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Weed Control: Sodium Chlorate as a Herbicidal Agent in Pastures

By FRANCIS E. HANCE

Ingestion of about one pound of sodium chlorate by a full-grown steer has been found fatal to the animal. In spite of this fact, controlled chlorate spraying in pastures to destroy weeds need occasion no harm to grazing animals nor constitute any other serious hazard. The subject is discussed very briefly. Authoritative recommendations are quoted from mainland research workers for using and handling chlorates. Further suggestions are submitted.

Sodium chlorate is employed extensively on the mainland and to an appreciable extent in Hawaii in controlling weed growth and other obnoxious plants in pasture lands and on ranches.

In view of the fact that this chemical is ordinarily reduced to common salt in the presence of organic matter and moisture, it has been classed as harmless to animals after its application in the field.

It has been noted in Hawaii that for several days following a chlorate spraying on tall grass the fire hazard is distinctly increased and that a flame or spark applied to a spot in the dried, treated area is rapidly and, in some cases, explosively transmitted to the rest of the dried matter in the sprayed section. To circumvent the accidental combustion of chlorate-sprayed vegetation it has been the custom to include an amount of calcium chloride in the spray solution equal to the weight of chlorate used. The hygroscopic nature of the chloride, of course, retains sufficient moisture on the sprayed plants to act as a retardent of spontaneous or vigorous combustion. Hence it appears likely that the reduction of the major portion of sodium chlorate to sodium chloride on the sprayed plants takes place only after a contact period of several days—perhaps a week, or even longer.

Recently, in Hawaii, experimental studies on the eradication of fire bush in pastures have developed a technic of applying dry sodium chlorate on the soil directly

at the base of the bush, and in contact with the incised main stem or trunk of the plant.

In discussing this subject with Dr. J. M. Hendershot, Chief, Department of Bacteriology and Pathology, Board of Agriculture and Forestry, Territory of Hawaii, he pointed out the danger of indiscriminate use of sodium chlorate in areas where grazing animals might have access to the chemical, on or off vegetation, before it had been reduced to table salt—as it is—in its herbicidal function. Dr. Hendershot cited previous experiences he had gained on the mainland in clinical studies of the effects of ingested chlorates on grazing animals and submitted several recent papers by former colleagues dealing with the problem.

It has been stated here previously that sodium chlorate persists unaltered for some time on sprayed vegetation. The saline taste of the chemical makes it attractive to the animal. Moore (4) of the Department of Surgery and Medicine, Kansas State College, observes that apparently little, if any, reduction of chlorate to chloride occurs in the body of the animal and hence its poisonous effect continues even to the point where partial elimination occurs in the urine. He adds that absorption in the animal is rapid and the toxic action is violent and prolonged. Where elimination is impeded, chlorates produce an actual asphyxia when about 75 per cent of the blood hemoglobin has been affected.

Laird (2) explains that there are indications that the injurious action of chlorates on animals may be due to their combination with hemoglobin of the blood to form methemoglobin, thus diminishing the oxygen-transporting power of the blood stream.

McCulloch and Murer (3) in a discussion on the subject point out that while it is true that livestock can consume moderate amounts of chlorate-treated weeds without harm this fact in itself (and generally recognized) has occasioned a certain amount of carelessness in handling and distributing the chemical. They reiterate essentially the same observation made previously here, *i.e.*, that the harmless nature of chlorate-sprayed vegetation (when it is harmless) may be dependent upon vital time and chemical environmental elements which carry the chlorate on the weed surfaces entirely or principally to the inocuous salt, sodium chloride.

McCulloch and Murer (3) have published a recommendation to live stock growers on the use of chlorates. Their advice is practical, straightforward and makes good chemical sense. It follows:

"It was recommended that the use of sodium chlorate in the control of noxious weeds be continued, but that the following precautions be taken:

"1. The range be heavily salted at least a week before the sodium chlorate is applied, and the salt be replenished frequently so that plenty will remain in the troughs as long as there is any sodium chlorate on the ground;

"2. all lumps of sodium chlorate either be broken up or dissolved in water;

"3. that only reasonable amounts, *i.e.*, not over 5 pounds per square rod, be applied;

"4. that great care be taken not to spill the chemicals on the ground where cattle would have access to small piles; and

"5. that partially used drums be placed where cattle can not reach them."

Former practice in Hawaii employed sodium chlorate in spray solution at the rate of one pound of chemical in one gallon of water. As an expedient (*a*) in reduc-

ing the costs of preparing chlorate spray solutions, (*b*) in minimizing the fire hazard, (*c*) in making the residue less attractive to animals and (*d*) to take advantage of the synergetic action of the H.S.P.A. Activator* (patent pending) upon the chlorate herbicide, the author (1), in 1940, recommended an activated spray solution for ranchmen in Hawaii which has been used with some success.

A typical activated chlorate spray, containing but one-fifth the chlorate fraction of standard practice and which appears to be equally as effective, is prepared by dissolving 20 pounds of sodium chlorate and 4 pounds of H.S.P.A. Activator in 100 gallons of water. The physical characteristics of the activated solution preclude the necessity of adding to it any "wetting" or "spreading" agents.

In view of the additional hazards of chlorate sprays, as recently reported, it may be suggested that the cheaper and equally effective activated chlorate solutions might prove generally more satisfactory to all stockmen using this chemical in weed control.

Literature Cited

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* The sodium salt of pentachlorophenol.

Leaf-punch Nitrogen Studies on First Ratoon Crop of 32–8560 at Waipio

By M. Doi

An attempt has been made to develop an index of the nitrogen requirement of sugar cane in a study of the progressively changing nitrogen fraction in the blades of the plant at frequent intervals during its growing cycle. The progress of the research is discussed, together with the difficulties encountered in accurately appraising the observations and data, and in finding therein the groundwork for a reliable criterion in the control of fertilization with this nutrient.

Three field experiments at Waipio, Oahu (Experiments 108 ATN, 109 N and 110 AN) are cooperative studies related to the nitrogen nutrition of sugar cane. One of the objectives of these tests is the evaluation of the leaf-punch technic as a criterion for nitrogen fertilization.

According to usual plantation practice, nitrogen fertilization control is based mainly upon results of field experiments which are carried out with predetermined amounts of nitrogen applied in accordance with fixed schedules. The results of the different treatments are studied to determine the optimum application and also to estimate the nitrogen fertilization for the succeeding crop. However, results obtained from a series of these experiments have generally indicated that the optimum treatment is not constant. Variable results are caused to a large extent by the meteorological variations which occur from year to year (3, 6).

The system of fertilization control by leaf-punch nitrogen analyses, by determining the nitrogen content in the active leaf tissues at various chronological stages of crop development, seeks to have the plant indicate its nutrient requirement. This method of determining the nitrogen needs of sugar cane was proposed by Yuen and Hance (8) on the basis of the relationships established by them as existing between the nitrogen levels in the leaf samples and growth (elongation) of cane, and the correlation which they found exists between the percentage of nitrogen in the leaves and the fertilizer applied. The objective of the control is to maintain an optimum balance between growth of cane and sugar storage by controlling nitrogen levels in the leaf tissues according to the levels tentatively established by Yuen and Hance from their studies with H 109 cane. These levels were: an optimum percentage of 2.0 per cent for the initial six months of growth, above which nitrogen appears to be excessive; a minimum percentage of 1.0 per cent, desirable at harvest; and poverty adjustment* between 2.0 and 1.0 per cent. Briefly stated, the plan of con-

* The theory advanced by Paul Macy in "The quantitative mineral nutrient requirements of plants," *Plant Physiology* 11: 749–764, 1936, on the relationship existing between the percentage content of a nutrient in a plant and the sufficiency of the nutrient for growth, has been proposed for application in a method to determine the mineral requirements of plants by plant analysis. The dominant concept of this theory is a critical percentage of each nutrient in each kind of plant, above which there is luxury consumption and below which there is poverty adjustment which proceeds until a minimum level is reached.

trol calls for the determination of nitrogen percentages in the leaf-punch samples collected at regular and progressive intervals throughout the growth cycles of a crop. The nitrogen indices thus obtained are plotted against tentative standards and serve as indicators of sufficiency or deficiency of nitrogen at the date of sampling. Interpretation of these data, in the light of other similar results and experiences, serves as a guide in determining the amount of fertilizer to be applied as the crop progresses, as well as the time of fertilization. The nitrogen content of the plant, as indicated by this method of fertilization control, is believed to be directly related to growth (8). Although the leaf-punch nitrogen has been confirmed as a reliable index of the nitrogen levels in the green top of the plant for the Clements' method of crop control (5), the relation of its level alone to the final sugar yield has not been well established (2, 8). The purpose of this paper is to present the results of leaf-punch analyses on the first ratoon crop of 32–8560 cane and to indicate the applicability of the system, proposed as a method for field control of nitrogen, to this particular variety of cane.

Review of the Plan

In Experiments 108 ATN and 110 AN, predetermined differential nitrogen applications, both in time and amounts, were made. Results of leaf-punch analyses in these two tests were later correlated with yields and other data. In Experiment 109 N one series of plots (control) received nitrogen fertilization in predetermined amounts, while another series of plots received nitrogen as determined by the system of leaf-punch analyses. These experiments were installed and planted to the variety 32–8560 on August 1, 1940; the plant crop was harvested on May 2–17, 1942 at the age of 21 months.

The first ratoon crop was started on May 25, 1942. The data and discussions which follow refer to Experiment 109 N which was set up for the study of the leaf-punch technic as a method of determining the time and amounts of nitrogen which should be applied to the crop if maximum yields were to be obtained.

Experiment 109 N consisted of seven plots (Treatment "C," or control) in which the predetermined application for the entire crop was 160 pounds of nitrogen per acre, and seven plots (Treatment "L") in which the amounts and time of applying nitrogen were to be determined by the leaf-punch analyses, except that 40 pounds of nitrogen were applied as the presumed initial requirement. Adjacent to this area were three "X" plots which received no nitrogen, the results from which form the basis of this discussion.

Irrigation and Weather Data

A great deal of attention has been directed toward the "cause and effect" relationships existing between the nitrogen and other growth factors, such as atmospheric energy and water (3, 4, 6). Therefore, irrigation data and accumulated rainfall, and average day-degrees at each monthly sampling interval are presented (Fig. 5) with the hope that these records may render a better and more conclusive interpretation of the leaf-punch data.

Fertilization

Ammonium sulfate and muriate of potash were applied by hand to the cane row immediately after irrigation, as follows:

Treatments	(1) 7/1/42 N	(2) 9/10/42 N	(2) 9/10/42 K_2O	(3) 10/16/42 N	(4) 10/23/43 N	(5) 4/14/43 N	Totals N	Totals P_2O_5	Totals K_2O
	Dates and amounts per acre								
C............	40	60	100	0	60	0	160	0	100
L............	40	60	100	60	0	60	220	0	100
X............	0	0	100	0	0	0	0	0	100

The "C" plots received all of the predetermined amounts of nitrogen in three applications according to fixed schedules. On the other hand, the "L" plots received nitrogen as required by the leaf-punch control, except the first 40 pounds applied as the presumed initial requirement. No phosphate was applied to the crop.

Sampling

The leaf-punch sampling for the first ratoon crop was initiated on July 15, 1942, at the crop age of 1½ months, just two weeks after the first application of 40 pounds of nitrogen fertilization. Thereafter, leaf-punch specimens were taken at regular intervals. The sampling procedure was similar to that of the previous plant crop. A sample was taken from ten primary stalks of which the second, third and fourth visible dewlap leaves were punched. Sixty leaf-punch disks (two disks from each leaf) constituted a sample.

Results and Discussion

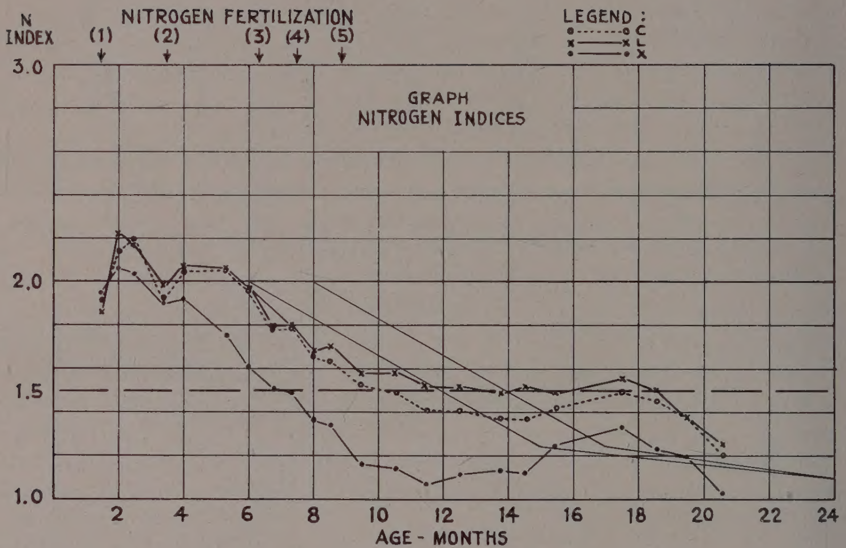
Since the results of leaf-punch studies obtained by previous investigators on the plant crop of Experiment 109 N have not been published, they are presented herein (Table I and Fig. 1) because they are considered relevant in interpreting the results obtained from the first ratoon crop. (For the harvesting results, see Table V.)

TABLE I

WAIPIO EXPERIMENT 109 N

Nitrogen Indices of the Plant Crop (Averages for Plots C–L–X)

Date sampled	Age sampled	Plots C	Plots L	Plots X
9/10/40	5½ weeks	1.92	1.86	1.94
10/1/40	2 months	2.14	2.22	2.07
10/15/40	2½ "	2.19	2.17	2.04
11/12/40	3⅗ "	1.92	1.98	1.90
12/3/40	4 "	2.05	2.07	1.92
1/7/41	5¼ "	2.05	2.06	1.75
2/3/41	6 "	1.96	1.97	1.61
2/24/41	6¾ "	1.78	1.79	1.51
3/10/41	7⅓ "	1.79	1.80	1.49
3/31/41	8 "	1.65	1.68	1.36
4/14/41	8½ "	1.63	1.70	1.34
5/12/41	9½ "	1.52	1.58	1.16
6/16/41	10½ "	1.49	1.58	1.14
7/14/41	11½ "	1.40	1.52	1.07
8/11/41	12½ "	1.40	1.51	1.11
9/22/41	13¾ "	1.37	1.48	1.13
10/13/41	14½ "	1.37	1.51	1.12
11/12/41	15½ "	1.42	1.49	1.25
1/12/42	17½ "	1.49	1.55	1.33
2/18/42	18½ "	1.45	1.50	1.23
3/16/42	19½ "	1.38	1.37	1.19
4/20/42	20½ "	1.20	1.25	1.02



Fertilization: Pounds Nitrogen per Acre
(Source of nitrogen—ammonium sulfate)

No.	Date	Plots C	Plots L
1	9/16/40	40	40
2	11/16/40	60	60
3	2/10/41	0	40
4	3/17/41	60	40
5	4/26/41	0	40
Total		160	220

Fig. 1. Nitrogen indices and fertilization of the plant crop.

Under the leaf-punch system of controlling the nitrogen levels in cane leaves (8) the initial growth is supposed to be conditioned by maintaining a nitrogen index at approximately two per cent for the first six months. The nitrogen levels should then commence to drop gradually with continued growth of the crop. Finally, the minimum nitrogen level of approximately one per cent is expected to be reached during the period of ripening. With the suggested nitrogen levels and results of leaf-punch studies obtained from the previous plant crop in mind, the nitrogen levels of the first ratoon will now be discussed. (Refer to Table II and Fig. 2.)

The indices of the "C" and "L" plots at the crop age of 1½ months, *i.e.*, two weeks after the initial application of 40 pounds of nitrogen, were about 1.6 per cent —significantly lower than the suggested level of two per cent. However, the index of the "X" plots which received no nitrogen was also approximately 1.6 per cent. It was assumed that the response to 40 pounds of nitrogen was not then realized in the "C" and "L" plots. Therefore, no immediate application of nitrogen was made.

The results of the second sampling, made on August 17, 1942, one month after the first collection, indicated that there was no appreciable lowering of the nitrogen levels in the "C" and "L" plots, but there was a significant drop in the "X" plots. Considering the suggested nitrogen limits (two per cent) for the cane at this age

of 2½ months, the index of 1.6 per cent indicated an apparent need for nitrogen at this point. Since the test required that subsequent fertilization of the "L" plots be made by leaf-punch control, it was suggested that at least 60 pounds of nitrogen be applied to the "L" plots immediately. However, the application of nitrogen to the "L" plots was not made until September 10, 1942, when the "C" treatment received

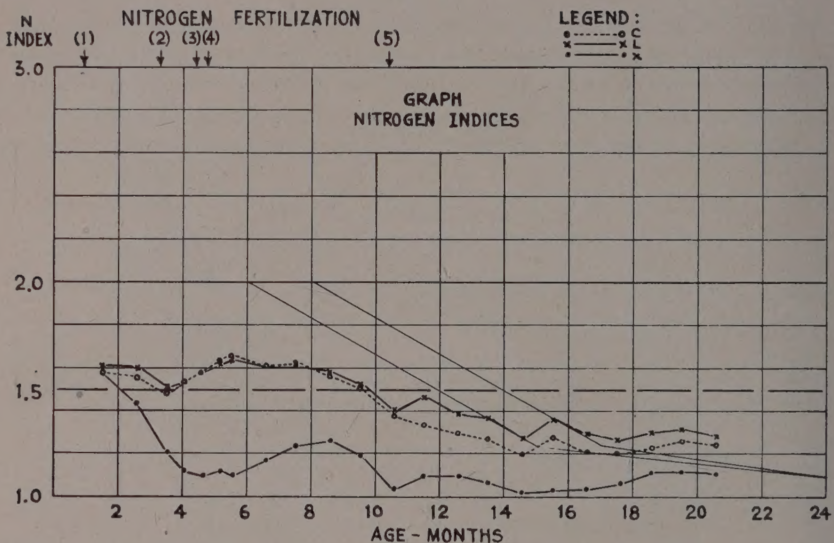
TABLE II

WAIPIO EXPERIMENT 109 N

Nitrogen Indices of the First Ratoon Crop (Averages for Plots C–L–X)

Date sampled	Age sampled	Plots C	L	X
7/15/42	1½ months	1.58	1.61	1.57
8/17/42	2½ "	1.56	1.60	1.44
9/14/42	3½ "	1.48	1.51	1.21
9/30/42	4 "	1.54	1.54	1.12
10/15/42	4½ "	1.58	1.58	1.10
11/5/42	5⅛ "	1.63	1.62	1.12
11/16/42	5½ "	1.65	1.64	1.10
12/15/42	6½ "	1.61	1.61	1.17
1/18/43	7½ "	1.62	1.61	1.24
2/15/43	8½ "	1.57	1.58	1.26
3/15/43	9½ "	1.51	1.52	1.20
4/20/43	10½ "	1.38	1.40	1.04
5/17/43	11½ "	1.34	1.47	1.10
6/15/43	12½ "	1.30	1.39	1.10
7/15/43	13½ "	1.27	1.37	1.07
8/16/43	14½ "	1.20	1.27	1.02
9/15/43	15½ "	1.28	1.36	1.03
10/15/43	16½ "	1.21	1.29	1.04
11/15/43	17½ "	1.20	1.26	1.06
12/16/43	18½ "	1.23	1.30	1.11
1/17/44	19½ "	1.26	1.32	1.12
2/14/44	20½ "	1.24	1.28	1.11

its predetermined 60 pounds of nitrogen. This slight delay was due to an acute labor shortage. The 60-pound application of nitrogen increased the nitrogen index from 1.51 per cent, at the age of 3½ months, to 1.58 per cent one month after fertilization —less than a one-tenth per cent rise, and leaving a four-tenths per cent requirement to reach the prescribed level of two per cent. Another 60 pounds of nitrogen was added to the "L" plots at the age of 4½ months on Oct. 16, 1942, in an attempt to boost the nitrogen index. An increase of but 0.04 per cent resulted. The "C" plots received the predetermined 60 pounds of nitrogen by the third and last application on October 23, 1942, one week after the third application was made to the "L" plots. No significant difference in the nitrogen levels was noticed between the "C" and "L" treatments up to the time the fourth application of nitrogen was made to the "L" plots, both treatments having received 160 pounds of nitrogen up to that point. It is worthy of note that the nitrogen index of 1.65 per cent was the maximum for either treatment during the entire period of growth, although the cane had received 160 pounds of nitrogen by the age of 4½ months. The nature of the index curve for the first ratoon is very different from that of the plant crop during the first six months of growth. The nitrogen indices of the "C" treatment (control) of the plant crop, together with those of the first ratoon crop, are presented for comparison both upon the basis of ages (Fig. 3), and on the basis of the month of sampling



Fertilization: Pounds Nitrogen per Acre
(Source of nitrogen—ammonium sulfate)

No.	Date	Plots C	Plots L
1................	7/1/42	40	40
2................	9/10/42	60	60
3................	10/16/42	0	60
4................	10/23/42	60	0
5................	4/14/43	0	60
Total		160	220

Fig. 2. Nitrogen indices and fertilization of the 1st ratoon crop.

(Fig. 4). The "C" treatment, or 160-pound nitrogen application, was considered optimum for the plant crop.

In view of the low nitrogen level in the young ratoon crop, the question of additional fertilization had to be considered. Based on the assumed standards of sufficiency for a 5½-month crop, the leaf-punch nitrogen at 1.64 per cent showed a need for additional fertilization. However, other growth factors had to be considered. The crop was 5½ months of age by the middle of November. Hence it was assumed, in perspective, that growing weather for the following winter months would not be optimum. The leveling off of the nitrogen curve of the "X" or no nitrogen plots was interpreted as a manifestation of unfavorable weather for growth (Figs. 2 and 4). Also considered was the requirement of the previous crop. Since the optimum for the plant crop was believed to be about 160 pounds, and since the quantity of nitrogen added to date to the ratoon totaled 160 pounds, the matter of making further additions of fertilizer was given careful consideration. Moreover, sufficient information not being available concerning the nitrogen levels in leaf-punch specimens of ratooned 32–8560 cane, the decision was made to omit fertilization pending the results obtained at the next sampling period.

The index of 1.6 per cent was approximately maintained from Oct. 15, 1942, to February 15, 1943—a period of four months—at the crop ages of from 4½ to

8½ months. However, the index of the "X" treatment, which had received no nitrogen, rose from 1.10 per cent to 1.26 per cent during the same period. These results differ from those of the plant crop in which the nitrogen indices showed a definite drop in all treatments during the corresponding age period (Fig. 1). It is a matter of interest to note here that there was unusually heavy rainfall during the period from November, 1942, to the middle of January, 1943 (Fig. 5), and that a large portion of the cane lodged.

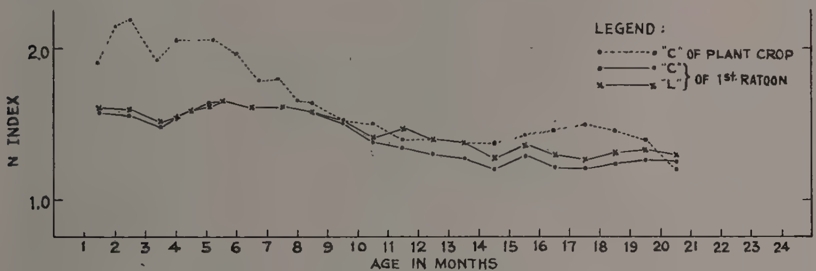


FIG. 3 - NITROGEN INDICES OF 1st RATOON COMPARED WITH "C" (CONTROL) OF PLANT CROP BY AGES

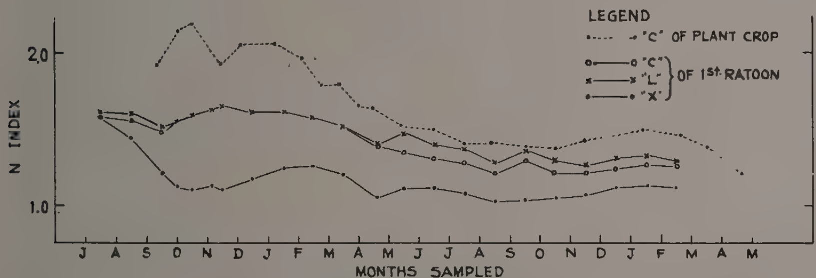


FIG 4 - NITROGEN INDICES OF 1st RATOON COMPARED WITH "C" (CONTROL) OF PLANT CROP BY MONTHS SAMPLED

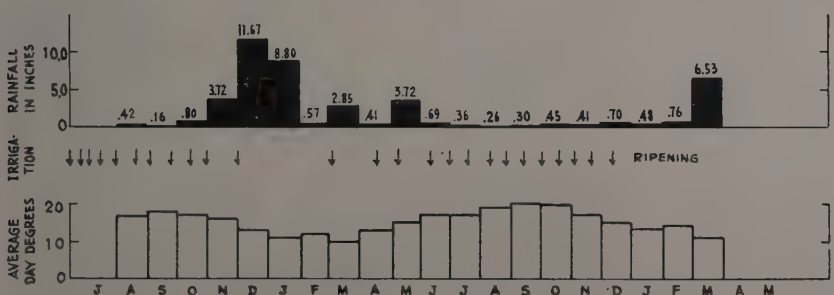


FIG. 5 - IRRIGATION DATA AND AVERAGE DAY-DEGREES AND ACCUMULATED RAINFALL AT MONTHLY SAMPLING INTERVAL

When the spring season set in, the nitrogen level commenced to drop. The index of the "L" plots at 10½ months in April of 1943 was 1.40 per cent, which was almost 0.1 per cent lower than that of the "C" treatment of the plant crop at the corresponding age. When compared according to the time (month) of sampling,

this difference would be increased to about 0.2 per cent. (Fig. 4.) The crop still had a considerable period of favorable weather ahead. Therefore, an additional 60 pounds of nitrogen were applied to the "L" plots on April 14, 1943, making the total application 220 pounds, as against 160 pounds for the "C" treatment. The nitrogen level of the "L" plots rose to about 1.5 per cent at 11½ months and then started to drop gradually. However, this additional fertilization was found to be uneconomical, for it did not result in an increase in sugar yield at harvest, 11 months after the last application of nitrogen to the "L" plots (refer to harvesting results in Table IV).

At the time the last 60 pounds of nitrogen were applied to the "L" plots a supplementary leaf-punch study was made on the sucker plants concurrently with the regular sampling. The first series of samples was collected from the suckers (about six feet tall) six days after the nitrogen application; the second series of specimens was taken from the same suckers one month after the first sampling. (A sample was taken from ten sucker plants.) Analytical data thus obtained, together with the results of the regular leaf-punch samples, collected at the corresponding times, are presented in Table III.

TABLE III

COMPARISON OF NITROGEN INDICES OF SUCKERS AND PRIMARY STALKS

Samples Taken on 4/20/43, Six Days After Application of 60 Pounds of Nitrogen to the "L" Plots

Suckers				Primary stalks			
Plots	% T.N.	Plots	% T.N.	Plots	% T.N.	Plots	% T.N.
C 41	1.46	L 42	1.53	C 41	1.42	L 42	1.44
43	1.42	44	1.50	43	1.38	44	1.43
45	1.48	46	1.48	45	1.40	46	1.37
48	1.51	47	1.52	48	1.39	47	1.43
49	1.43	50	1.47	49	1.33	50	1.38
52	1.49	51	1.51	52	1.35	51	1.39
53	1.49	54	1.46	53	1.38	54	1.36
Aver.	1.47±.01	Aver.	1.50±.01	Aver.	1.38±.01	Aver.	1.40±.01
Std. deviation	.03		.03	Std. deviation	.03		.03

Samples Taken on 5/17/43, Approximately One Month After the First Sampling

Suckers				Primary stalks			
Plots	% T.N.	Plots	% T.N.	Plots	% T.N.	Plots	% T.N.
C 41	1.42	L 42	1.66	C 41	1.30	L 42	1.49
43	1.49	44	1.70	43	1.35	44	1.46
45	1.48	46	1.55	45	1.38	46	1.47
48	1.49	47	1.63	48	1.37	47	1.50
49	1.42	50	1.62	49	1.27	50	1.51
52	1.40	51	1.67	52	1.33	51	1.50
53	1.52	54	1.53	53	1.36	54	1.38
Aver.	1.46±.02	Aver.	1.62±.02	Aver.	1.34±.02	Aver.	1.47±.02
Std. deviation	.05		.06	Std. deviation	.04		.04

Reference to Table III reveals that young suckers had a significantly higher nitrogen level than the primary stalks, regardless of the difference in the amount of nitrogen which was applied. Following the application of nitrogen to the "L" plots in April, both the suckers and the primaries increased in per cent total nitrogen. Of interest is the evidence which indicates that the young suckers obtained a much higher percentage of nitrogen than the primaries during the one-month period be-

tween April and May. In the "C" plots which received no nitrogen in April there were no significant changes in the nitrogen indices of either the suckers or the primaries. While the data pertaining to sucker plants are not as extensive as might be desired, they appear to indicate that the status of young suckers in a field, when they have a substantial period of growth ahead, should perhaps be given more consideration in determining a critical nitrogen level in the plant, for their inclusion will give a more representative sample from which to evaluate the nitrogen requirement of the crop.

The results of nitrogen determinations on these plant and first ratoon crops of 32–8560 cane raise two important questions: Do the lower nitrogen levels during the period of growth of young 32–8560 cane, when compared with the standards proposed by Yuen and Hance (8), working with H 109 cane, indicate a varietal difference in nitrogen absorption and/or utilization as suggested by Cornelison (7)? Was the failure of the ratoon cane to reach the nitrogen levels of the plant crop during the first nine months of growth due to environmental factors; if not, to what could this failure be ascribed? It is difficult to believe that cane which had received 160 pounds of nitrogen at the age of about five months was insufficiently supplied.

In September, when the crop was about 15 months old, the gradual decline of the nitrogen indices which commenced in the spring and continued throughout the summer stopped and thereafter remained higher than desirable up to the time of the final leaf-punch sampling made in February 1944 at the age of 20½ months. Thus the nitrogen levels on August 15, 1943, were 1.20 per cent for the "C" and 1.27 per cent for the "L" plots, and six months later, on February 14, 1944, they were 1.24 per cent and 1.28 per cent, respectively, much above the desirable level of about one per cent which has been suggested as ideal about the time of harvest. The expected final decline of the nitrogen index after irrigation was discontinued was not realized as in the case of the plant crop (Fig. 4). The rainy weather prior to harvest might have been one cause that hindered the final drop in nitrogen content. It is a matter of interest to note here that a somewhat similar status of nitrogen levels occurred in the plant crop during the period from September 1942 to January 1943 at the crop ages of from 13½ to 17½ months (Fig. 4). This tendency of the nitrogen indices to level off and then to rise after September of the second year may be interpreted as a manifestation of the seasonal change or a combined function of the season and the age of the plant.

The crop was harvested during the period from March 1 to March 14, 1944, at the age of 21½ months. A summary of average yields submitted by F. C. Denison is presented in the following table:

TABLE IV

SUMMARY OF AVERAGE YIELDS (FIRST RATOON)

Treatments	No. of plots	Total N/Ac.	TCPA	Y%C	TSPA
C	7	160	145.0	8.5	12.3
L	7	220	155.0	8.4	12.8

(For statistical significance a minimum difference of 13.8 in TCPA and of 0.6 in TSPA are indicated requirements.)

Statistically, no significant gains were secured from the "L" treatment which received the nitrogen in accordance with the nutrient content of the plant as indicated by the leaf-punch analyses. What the result might have been if the crop had

been harvested at a more advanced age when the leaf-punch nitrogen had dropped to the tentative level of approximately one per cent is an open question in view of the leaf-punch study, for the nitrogen indices of the "C" and "L" plots at the age of 20½ months were 1.24 per cent and 1.28 per cent, respectively, indicating that the crop may not have been ready for harvest at that time. The undesirably high nitrogen levels, coupled with rainy weather prior to and during harvest, appears to be associated with the poor juice quality.

For comparison, a summary of average yields of the plant crop follows:

TABLE V

SUMMARY OF AVERAGE YIELDS OF THE PLANT CROP

Treatment	Total N/Ac.	TCPA	Y%C	TSPA
C	160	121.4	12.9	15.6
L	220	123.1	12.5	15.3

General Discussion

Results of leaf-punch studies on the first ratoon crop of 32–8560 cane have been presented and discussed according to nitrogen index data obtained at regular and progressive intervals from the start of the crop to harvest. Some difficulties encountered in the operation of this attempted crop control and significant features obtained are presented here for discussion.

During the first six months of growth, 1.65 per cent was the maximum nitrogen index obtained, regardless of different treatments. An attempt to raise the nitrogen percentage to approximately two per cent with a total of 160 pounds of nitrogen applied up to the age of 4½ months was not successful. It indicated that the level of two per cent, which has been suggested as an adequate index under six months of age, was not necessarily essential for this first ratoon crop. The leveling off of the nitrogen indices of the "C" and "L" plots, and the rising of the indices in the "X" or no-nitrogen plots may be interpreted as being caused by either a low rate of nitrogen assimilation or a contribution of nitrogen made by the soil, or by both. Hence a total of 160 pounds of nitrogen up to the age of 4½ months in October might have been excessive. However, this attempt to raise the nitrogen level was considered adequate because in the previous plant crop the nitrogen indices of the "C" and "L" treatments were maintained almost at the level of two per cent during the first six months.

When the crop was 10½ months old in April 1943, the index of the "L" plots was 1.40 per cent, which was 0.1 per cent lower than that of the optimum treatment of the plant crop at the corresponding age. However, the consequent additional application of 60 pounds of nitrogen did not result in an increase in sugar yield at harvest. Here again the result presented difficulty in defining an optimum nitrogen level at that time.

A tangible result obtained was that the nitrogen levels during the boom stage were below the prescribed suggested limits as was the case in the previous plant crop. Thus the optimum nitrogen level for 32–8560 cane during this stage appears to be lower than the prescribed lines which have been suggested as ideal for this period of poverty adjustment.

Reference to Fig. 3 and to Fig. 4 reveals that the parallelism existing between the nitrogen levels of the plant crop and those of the first ratoon is more apparent when compared on the basis of the time (month) of sampling rather than according

to the age of the crop. Thus the status of the nitrogen levels determined at the time of sampling should perhaps be given more consideration in interpreting the leaf-punch data.

In general the results of the studies revealed that the leaf-punch analyses reflected the different nitrogen levels in the active cane leaves resulting from the differences in available nitrogen supply, age and weather. However, as we have seen, the interpretation of the nitrogen indices for guidance of nitrogen fertilization for the first ratoon crop was not an easy matter. A major difference observed in the field between the plant and the first ratoon crop, aside from the authentic differences in the growth factors, was that the latter crop had more primary stalks to start with than the former. However, with leaf-punch analyses alone, the optimum nitrogen level for the early stage of growth was not definitely ascertained. Thus the operation of this crop control is still, to a large extent, a matter of speculation and may remain so until we arrive at some definite conclusion as to the exact meaning of the leaf-punch nitrogen in relation to the plant requirement. It is beyond our reach at present to define, for a crop at early ages, the specific nitrogen levels which insure an optimum sugar yield at final harvest.

We are continuing our studies on the second ratoon crop which is now well under way.

Acknowledgment

The writer wishes to express his appreciation to Dr. Hance and Mr. Boyen of the Chemistry department, and to Messrs. Borden and Smith of the Agricultural department for assistance and counsel; also to Messrs. Uyehara and Yamamoto of the Chemistry department for assistance in connection with the sampling of the experiments.

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The Vertical Distribution of Available (Exchangeable) Potassium in Oahu Soils*

By A. S. Ayres and C. K. Fujimoto

Although a good deal is known regarding levels of available potassium in the surface layers of Oahu soils, very little is known concerning the supplies of this element at greater depths in the soil. This paper reports a study of the supplies of potassium available to relatively deep-rooted plants such as sugar cane in zones below those tested by ordinary soil-sampling techniques.

The level of potassium was found in some soils to decrease with depth to the bottom of the section examined. In other soils the level decreased with depth for a distance of 1½ to 2 feet, but with greater depth rose again. It was found that analysis of the surface layer of soil only gives a very incomplete picture of the quantities of potassium available to such crops as sugar cane.

Although the levels of available potassium in Hawaiian soils have been studied extensively, such study has been confined almost wholly to the surface layers of the soils. As a consequence very little is known regarding the levels of available potassium at greater depths in the soil. Yet, with deep-rooting plants such as sugar cane, there seems little doubt that potassium at depths of several feet, if chemically available, is also positionally available.

That the roots of sugar cane penetrate well-aerated soils to considerable depths is a matter of common observation. In a quantitative study of the distribution of sugar cane roots under plantation conditions in Hawaii, Lee (8) found that nearly 20 per cent of the weight of the entire root system was to be found at depths exceeding two feet. Further evidence that soil at substantial depths may contribute to the mineral nutrition of sugar cane has been obtained by Evans (4) in Mauritius. This worker found that when chemically available minerals were present in the subsoil, they were vigorously absorbed by the deep roots. With deep-rooted varieties of sugar cane, such as Uba, Evans obtained exudates containing mineral materials from roots severed 15 feet below the surface of the soils.

Available potassium appears, from studies in other areas, to be variously distributed in the soil profile. Thus in five profiles typical of some 40 uncultivated, podzolic Scottish soils Mitchell (11) found that exchangeable potassium in two cases decreased, and in one case increased consistently to the bottom of the sections (80–130 cm.) examined. In the two remaining profiles, levels of potassium near the surface decreased with depth and then either became constant or fluctuated with greater depth. A more uniform distribution of exchangeable potassium was found by Lilleland (9) in alluvial orchard soils in California. In all but 4 of 23 soils examined to a depth of four feet by this worker potassium decreased to the bottom of the section. In the four remaining soils there was some increase in the fourth foot. Examination of a small number of soils to a depth of eight feet indicated

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little further decrease beyond the sixth to seventh foot. Study of Queensland sugar cane soils to a depth of two feet by Davidson (3) and of calcareous Arizona soils to a depth of three feet by McGeorge (10) revealed distribution patterns similar to those already noted.

No published record has been found dealing with the vertical distribution of available potassium in Hawaiian soils. Some study of the subject has been made, however, in connection with specific plantation problems, the results being contained in Experiment Station, H.S.P.A. reports. From these it is seen that Hance (7) examined the upper five feet of a profile in a sugar cane field soil at Puunene, Maui, and found that exchangeable potassium diminished from the surface of the soil to the bottom of the section. Profiles in two sugar cane field soils at Ewa, Oahu, were examined for exchangeable potassium to depths of five feet by Gow (6), who observed that potassium diminished with depth to about the two-foot level and remained constant from that point to the bottom of the section. It appears from the foregoing review that, as a rule, exchangeable potassium decreases with depth near the surface of the soil and at greater depths may continue to decrease, may remain constant, or even increase.

Description of the Soils Examined

The soils examined are essentially clay soils and are lateritic in nature. They include alluvial, residual and colluvial types. Elevations range from about 25 feet to approximately 1,000 feet and mean annual rainfall from about 20 to 90 inches. A water table exists near the surface in the case of one of the soils sampled (No. 43–91).

The majority of the soils studied are under cultivation, being principally devoted to the production of sugar cane. Due to the low rainfall in these areas agricultural soils are generally intensively irrigated. Only one of the soils examined (No. 42–19) is representative of an unirrigated agricultural soil. The soils examined, together with pertinent data, are listed in Table I.

Method of Sampling

A trench about six feet in length and 1½ to 2 feet in depth was dug and samples of soil shaved off one face of the trench. Following this operation borings were made in the bottom of the trench and additional samples taken to the desired depths.

In the case of the cultivated soils, which in every instance were planted either to sugar cane or to Napier grass, the trench was dug midway between and parallel to the lines. It is to be expected that samples taken in this location would differ somewhat in potassium content, particularly in the upper horizons, from those which might have been taken in the line itself, since, in the first place, it is in the line that the fertilizer and generally the irrigation water are applied and, in the second place, the concentration of roots is greatest in the line. However, there seemed little reason for selecting one site in preference to another and, since sampling between the lines was obviously the more practical method, samples were in every case obtained from this location.

Hawaiian soils, like lateritic soils in general, rarely possess the marked differentiation into horizons which is frequently made the basis for the study of soil profiles in other areas. In this connection it may be seen by reference to Table I that

TABLE I

DESCRIPTION OF SOILS, EXCHANGEABLE POTASSIUM AND pH VALUES

Number	Soil	Type	Elev. (ft.)	Mean annual rainfall (in.)	Color*	Vegetation	Depth (in.)	Potassium (m.e./100)	pH
42–17a	Nuuanu	Residual	850	85	dk-yel-Br	grass, fern (virgin)	0–6	.30	4.6
17b					"		6–12	.083	4.7
17c					"		12–24	.094	4.7
17d					"		24–36	.14	4.6
42–19a	Waimanalo	Colluvial	300	90	dk-yel-Br	Sugar cane	0–6	.44	5.0
19b					mod-yel-Br		6–12	.089	4.9
19c					"		12–24	.064	4.9
19d					"		24–36	.20	4.7
42–20a	Waimanalo	Colluvial	325	90	dk-yel-Br	guava, plum, ti, fern (virgin)	0–6	1.02	5.1
20b					"		6–12	.44	5.0
20c					"		12–24	.15	4.9
20d					"		24–36	.37	4.7
42–21a	Waimanalo	Colluvial	275	90	dk-yel-Br	Sugar cane	0–6	.92	5.4
21b					"		6–12	.18	5.1
21c					"		12–24	.095	4.9
21d					"		24–36	.36	4.8
42–22a	Aiea	Residual	800	75	mod-Br	Fern, ohia-lehua	0–6	.22	4.5
22b					"		6–12	.12	4.3
22c					"		12–24	.062	4.5
22d					"		24–36	.096	4.6
42–23a	Aiea	Residual	350	40	mod-Br	Sugar cane	0–6	.30	4.8
23b					wk to mod-Br		6–12	.30	4.8
23c					mod-Br		12–24	.17	4.7
23d					"		24–36	.13	4.6
42–24a	Aiea	Residual	50	35	mod-Br	Sugar cane	0–6	.34	6.6
24b					"		6–12	.20	6.7
24c					wk-r-Br		12–24	.13	7.5
24d					"		24–36	.18	7.6
42–38a	Pensacola	Residual	200	40	dk-yel-Br	grass (virgin)	0–6	.43	6.3
38b					"		6–12	.18	6.6
38c					"		12–18	.11	6.7
38d					lt-yel-Br		18–24	.28	6.6
38e					"		24–29	.59	6.6
42–40a	Tantalus	Residual	1000	90	dk-yel-Br	Koa, guava, etc. (virgin)	0–6	.22	5.5
40b					"		6–12	.097	5.3
40c					"		12–18	.053	5.4
40d					"		18–24	.041	5.4
40e					"		24–30	.11	5.4
40f					"		30–36	.22	5.4
40g					"		36–42	.45	5.4
40h					"		42–48	.84	5.4
40i					"		48–54	.69	5.5
40j					"		54–60	.86	5.4
40k					"		60–66	.73	5.4
40l					"		66–72	.97	5.4
43–8a	Ewa	Alluvial	25	20	mod-Br	Sugar cane	0–6	.99	7.1
8b					"		6–12	.65	7.2
8c					"		12–18	.41	7.3
8d					"		18–24	.36	7.3
8e					"		24–30	.30	7.2
8f					"		30–36	.29	7.2
8g					"		36–42	.27	6.9
8h					"		42–48	.27	6.8
8i					"		48–54	.26	6.8

* U.S.D.A. color names for soils (12).

Abbreviations used in designating colors:

Br—brown. br—brownish. mod—moderate. wk—weak. Gr—gray. r—reddish. dk—dark. str—strong. yel—yellowish. lt—light.

Colors determined on air-dry 20-mesh soils.

TABLE I (Continued)

DESCRIPTION OF SOILS, EXCHANGEABLE POTASSIUM AND pH VALUES

Number	Soil	Type	Elev. (ft.)	Mean annual rainfall (in.)	Color*	Vegetation	Depth (in.)	Potassium (m.e./100)	pH
43–9a	Ewa	Alluvial	75	20	wk-Br	Sugar cane	0–6	.32	7.1
9b					"		6–12	.19	7.1
9c					"		12–18	.16	7.0
9d					"		18–24	.15	6.5
9e					"		24–30	.15	5.4
9f					"		30–36	.16	4.8
43–10a	Ewa	Residual	75	20	dk-yel-Br	Sugar cane	0–6	.97	7.4
10b					mod-yel-Br		6–12	.27	7.3
10c					"		12–18	.20	7.2
10d					"		18–21	.19	7.2
43–11a	Ewa	Alluvial	50	20	mod-Br	Sugar cane	0–6	.78	7.4
11b					"		6–12	.19	7.2
11c					"		12–18	.14	7.0
11d					"		18–24	.15	6.9
11e					"		24–30	.17	6.8
11f					"		30–36	.17	6.8
11g					"		36–42	.18	6.8
11h					"		42–48	.18	6.5
43–16a	Poamoho	Residual	700	45	mod to dk-Br	Napier grass	0–6	.20	6.6
16b					"		6–12	.17	6.7
16c					mod-Br		12–18	.17	6.6
16d					mod to str-Br		18–24	.14	6.6
16e					"		24–30	.19	6.8
16f					"		30–36	.22	6.9
16g					"		36–42	.24	6.9
16h					"		42–48	.23	6.8
43–33a	Poamoho	Residual	700	45	wk-r-Br	None	0–12	.50	5.4
33b					"		12–24	.25	6.3
33c					"		24–36	.27	6.1
43–34a	Ewa	Residual	350	20	wk-Br	cactus, grass (virgin)	0–6	.83	5.6
34b					"		6–12	.27	6.3
34c					"		12–18	.16	6.8
34d					"		18–24	.17	6.7
34e					"		24–30	.13	6.7
34f					"		30–36	.12	6.6
34g					"		36–42	.12	6.3
34h					"		42–48	.11	6.3
43–36a	H.A.E.S. Manoa	Alluvial	150	35	wk to dusky-Br	Napier grass	0–6	.53	6.3
36b					"		6–12	.48	6.4
36c					"		12–18	.42	6.4
36d					"		18–24	.41	6.4
36e					"		24–30	.39	6.6
36f					"		30–36	.38	6.6
43–43a	Makaha	Alluvial	50	20	wk-Br	Sugar cane	0–6	.73	7.0
43b					"		6–12	.59	6.9
43c					"		12–18	.31	7.0
43d					pale to wk-Br		18–24	.31	7.0
43e					"		24–30	.29	7.5
43f					"		30.36	.12	7.6
43g					"		36–42	.075	7.7
43h					"		42–48	.073	7.7

* U.S.D.A. color names for soils (12).

Abbreviations used in designating colors:

Br—brown. br—brownish. mod—moderate. wk—weak. Gr—gray. r—reddish. dk—dark. str—strong. yel—yellowish. lt—light.

Colors determined on air-dry 20-mesh soils.

TABLE I (Continued)

DESCRIPTION OF SOILS, EXCHANGEABLE POTASSIUM AND pH VALUES

Number	Soil	Type	Elev. (ft.)	Mean annual rainfall (in.)	Color*	Vegetation	Depth (in.)	Potassium (m.e./100)	pH
43–44a	Waianae	Alluvial	50	20	wk-Br	Sugar cane	0–6	1.06	7.5
44b					pale to wk-Br		6–12	.62	7.4
44c					"		12–18	.23	7.4
44d					"		18–24	.17	7.4
44e					"		24–30	.15	7.4
44f					"		30–36	.14	7.3
44g					"		36–42	.14	7.3
44h					"		42–48	.11	7.3
43–45a	Lualualei	Alluvial	75	20	wk-Br	Sugar cane	0–6	1.38	7.8
45b					br-Gr to wk-Br		6–12	.95	7.7
45c					"		12–18	.48	7.5
45d					wk to mod-Br		18–24	.29	7.5
45e					"		24–30	.29	7.2
45f					pale to wk-Br		30–36	.24	7.3
45g					"		36–42	.19	7.3
43–48a	Kunia	Residual	200	20	wk-r to mod-r-Br	Sugar cane	0–6	.19	6.5
48b					"		6–12	.13	6.7
48c					"		12–18	.088	7.0
48d					"		18–24	.095	7.1
48e					"		24–30	.092	7.0
48f					"		30–36	.094	7.0
48g					"		36–42	.098	6.9
48h					"		42–48	.11	6.9
43–49a	Waipahu	Residual	250	25	wk-r-Br	Sugar cane	0–6	.094	6.1
49b					"		6–12	.079	6.1
49c					"		12–18	.075	6.4
49d					"		18–24	.085	6.4
49e					"		24–30	.11	6.4
49f					"		30–36	.13	6.4
49g					"		36–42	.094	6.4
49h					"		42–48	.095	6.4
49i					"		48–54	.095	6.4
49j					"		54–60	.071	6.4
49k					"		60–66	.065	6.5
49l					"		66–72	.047	6.6
49m					"		72–78	.037	6.6
49n					"		78–84	.037	6.6
43–50a	Waipahu	Residual	400	30	wk-r-Br	Sugar cane	0–6	.43	6.3
50b					"		6–12	.15	6.2
50c					wk-r mod to r-Br		12–18	.091	6.3
50d					"		18–24	.083	6.4
50e					"		24–30	.076	6.5
50f					"		30–36	.054	6.5
50g					"		36–42	.040	6.4
50h					"		42–48	.034	6.4
43–66a	Waialua	Alluvial	20	30	wk to mod-Br	Sugar cane	0–6	1.09	6.6
66b					"		6–12	.87	6.7
66c					"		12–18	.45	6.5
66d					pale to wk-Br		18–24	.26	6.5
66e					"		24–30	.22	6.4
66f					"		30–36	.21	6.4
66g					"		36–42	.20	6.3
66h					"		42–48	.21	6.3

* U.S.D.A. color names for soils (12).
Abbreviations used in designating colors:
Br—brown. br—brownish. mod—moderate. wk—weak. Gr—gray. r—reddish. dk—dark. str—strong. yel—yellowish. lt—light.
Colors determined on air-dry 20-mesh soils.

TABLE I (Continued)

DESCRIPTION OF SOILS, EXCHANGEABLE POTASSIUM AND pH VALUES

Number	Soil	Type	Elev. (ft.)	Mean annual rainfall (in.)	Color*	Vegetation	Depth (in.)	Potassium (m.e./100)	pH
43–67a	Waialua	Alluvial	25	30	pale to wk-Br	Sugar cane	0–6	2.27	6.4
67b					"		6–12	1.90	6.3
67c					wk-Br		12–18	1.16	6.3
67d					"		18–24	.61	6.4
67e					wk to mod-Br		24–30	.75	6.4
67f					"		30–36	.83	6.3
43–68a	Waialua	Residual	175	30	wk to mod-Br	Sugar cane	0–6	.62	6.5
68b					"		6–12	.47	6.6
68c					"		12–18	.41	6.6
68d					"		18–24	.35	6.6
68e					wk-r-Br		24–30	.37	6.6
68f					"		30–36	.42	6.5
68g					"		36–42	.51	6.4
68h					"		42–48	.70	6.5
43–69a	Waialua	Residual	350	45	wk-r-Br	Sugar cane	0–6	.65	5.8
69b					"		6–12	.36	6.1
69c					wk to mod r-Br		12–18	.23	6.2
69d					"		18–24	.20	6.2
69e					"		24–30	.17	6.2
69f					"		30–36	.17	6.2
69g					"		36–42	.19	6.2
69h					"		42–48	.18	6.2
43–70a	Waialua	Residual	400	35	wk-r-Br	Sugar cane	0–6	.40	4.0
70b					"		6–12	.35	4.2
70c					wk to mod-r-Br		12–18	.27	3.9
70d					"		18–24	.23	4.6
70e					"		24–30	.23	4.7
70f					"		30–36	.24	4.7
70g					"		36–42	.25	4.7
70h					"		42–48	.26	4.7
43–90a	Kahuku	Alluvial	25	35	br-Gr to wk-r-Br	Sugar cane	0–6	.33	5.0
90b					"		6–12	.19	5.0
90c					"		12–18	.15	4.9
90d					"		18–24	.11	5.0
90e					"		24–30	.11	4.9
90f					"		30–36	.10	4.9
90g					"		36–42	.090	4.9
90h					"		42–48	.098	4.8
43–91a	Kahuku	Alluvial	25	50	br-Gr to wk-Br	Sugar cane	0–6	.22	6.1
91b					"		6–12	.22	6.3
91c					"		12–18	.12	6.3
91d					"		18–24	.048	6.1
91e					"		24–30	.042	5.7
91f					"		30–36	.039	5.1
91g					"		36–42	.072	4.0
91h					"		42–48	.078	4.1
44–17a	Waialua	Alluvial	25	30	br-Gr to wk-Br	Sugar cane	0–6	2.31	6.8
17b					"		6–12	2.35	6.9
17c					wk-Br		12–18	1.38	6.9
17d					"		18–24	1.17	7.0
17e					"		24–30	1.06	6.8
17f					"		30–36	1.30	6.9
17g					"		36–42	1.32	6.8
17h					"		42–48	1.29	6.8

* U.S.D.A. color names for soils (12).
Abbreviations used in designating colors:
Br—brown. br—brownish. mod—moderate. wk—weak. Gr—gray. r—reddish. dk—dark. str—strong. yel—yellowish. lt—light.
Colors determined on air-dry 20-mesh soils.

changes in color in the profile, where they exist at all, are moderate. Profile samples were accordingly taken on an arbitrary basis. During the first part of the study samples representing 6- and 12-inch horizons were obtained. Later, the sampling procedure was so modified that each sample represented a 6-inch horizon only.

The soils were initially sampled to a depth of three feet, but sampling was subsequently extended to include the fourth foot as well. In a few instances samples were obtained from depths somewhat greater than four feet. Some shallow soils were encountered and in these the depth of sampling was determined by the depth of the soil. No attempt was made to sample the entire soil profile (*i.e.,* from the surface of the soil down to the underlying unweathered material), where the depth of the profile exceeded four feet. The depths to which all samples were taken are indicated in Table I.

Methods of Analysis

Exchangeable potassium was chosen as the measure of available potassium. This fraction of the total soil potassium is generally considered to include all of the soil potassium available to plants at a particular moment. It is considerably greater in amount than the locally more familiar RCM* potassium, at least in Hawaiian soils.

Exchangeable potassium was extracted from the soils with normal ammonium acetate adjusted to pH 6.8. Potassium in the extracts was determined by the cobaltinitrite method of Volk and Truog (13).

pH values were measured with the glass electrode.

Experimental Results

The levels of exchangeable potassium in the profiles, together with the corresponding pH values, are presented in tabular form in Table. I. The former results are also depicted graphically in a series of bar-diagrams. In these diagrams each horizon in the profile is represented by a bar, the height of which indicates the level of potassium in the particular horizon. Levels of potassium are indicated in two ways: (*a*) in the conventional terms of milli-equivalents per 100 grams of oven-dry soil, and (*b*) in the more familiar terms of pounds K_2O per acre six inches of oven-dry soil. The latter values are to be found immediately above the bars.

Distribution of Available Potassium in the Soil:

Potassium appears to be distributed in the soils examined according to essentially three patterns. In the first of these patterns, exemplified by Figs. 1 to 8, potassium is at a maximum in the 0-to-6-inch horizon, except in the fields plowed a short time prior to sampling, and decreases with depth to the bottom of the section sampled. The decrease in level of potassium with depth may be a relatively gradual one, as in Figs. 2 and 5, or it may be very abrupt as, for example, in Figs. 3 and 8. In either case the diminution in the level of potassium is much more rapid in the upper portion of the section than in the lower. The lack of differentiation between the 0-to-6- and 6-to-12-inch horizons in soil 42–23 (Fig. 1) presumably resulted from the fact that the field had been plowed and otherwise cultivated a

* Rapid chemical methods of analysis, Experiment Station, H.S.P.A., Honolulu.

short time prior to sampling and hence the surface foot of soil had been rendered more or less uniform. The distribution of potassium in the Puunene soil examined by Hance (*7*) corresponds to the first pattern.

The second of the three distribution patterns is illustrated in Figs. 9–13. In this pattern, which may be regarded as a modification of the first type, potassium decreases with depth, but only to 18–24 inches. Below this point the level of potassium shows practically no change. This distribution pattern, which is present in some of the Ewa soils examined in this study, is also the pattern found by Gow (*6*) in his earlier examination of soils from this plantation.

In the first and second types of profiles, potassium is from 1½ to 13 times greater in amount in the surface six inches of soil than in the corresponding horizons containing the lowest levels of potassium.

Distribution of potassium in the soil profile according to the third pattern is indicated in Figs. 14 to 30. In these profiles potassium decreases downward from the surface to a point usually within the second foot, but with greater depth rises again. The increase above the minimum value is very slight in the cases of two or three of the soils. In the remainder of the soils of this class, however, the rise is marked, values sometimes reaching many times the minimal value. In three of the soils, levels of potassium at depths ranging from 2½ to 6 feet were even greater than those in the corresponding 0-to-6-inch layers of the soils. The lack of differentiation in potassium content between the 0-to-6- and 6-to-12-inch horizons in the case of soil 43–91 (Fig. 30) is explainable on the basis that the field was a very young plant field and hence mixing of the surface foot of soil had occurred not long before the soil was sampled.

Levels of potassium in the Tantalus profile (Fig. 21) change so irregularly with depth beyond the three-foot level, and this lack of uniformity is so unusual in the present study that a word of explanation may be in order. The Tantalus soil is a young soil which has been formed in place from volcanic ash and is not deeply weathered. No well-defined line of demarkation existed between the soil and the parent material at the point where the sample was taken, but from a depth of about three feet down to the bottom of the section the soil contained varying quantities of weathered ash and hence samples representing the deeper horizons contained disproportionate amounts of the two materials. It seems probable that this fact accounts for the observed irregularities in the potassium content of the section.

The quantities of potassium found in the alluvial Waialua soil (Fig. 26) were unusually high. In view of this fact and the common observation that alluvial soils of this type are frequently very non-uniform with respect to available mineral content, it was decided for the purpose of comparison to obtain samples from a second vertical section in another part of the same field. The levels of potassium in the horizons of the second profile section are illustrated in Fig. 28. Although the potassium contents of the 0-to-6-inch layers of the two sections are almost identical, in all horizons below this level potassium is even higher in the second section than in the first. The relationships between the potassium contents of the 0-to-6- and 6-to-12-inch horizons mean little in this case since the field had been plowed a short time before the samples were taken. Potassium is distributed in both sections from this field according to the third pattern, that is, potassium decreases to a minimum around the second foot and rises with greater depth.

Soil No. 43–49 (Fig. 31) does not appear to conform to any of the three distribution patterns. Thus there is practically no decrease in potassium with depth through the first foot or two of soil and a maximum occurs in the 30-to-36-inch horizon. This is followed by a gradual decrease. The low levels of potassium in all horizons of this profile tend, however, to magnify differences which in a soil better supplied with potassium might be ignored.

Total Quantities of Available Potassium in the Soils:

If the quantities of potassium present in the various soil horizons are added together some idea may be gained of the total amounts of potassium to which, to certain depths, the plants have access. The range in the levels of available potassium to depths of three and four feet are shown in Table II.

TABLE II

AVAILABLE (EXCHANGEABLE) POTASSIUM IN SOILS IN POUNDS K_2O PER ACRE

Soil zone	Virgin soils	Agric. soils
0 to 3 feet	370–1,485	335–5,635
0 to 4 feet	....	450–7,180

These ranges appear very large in view of the fact that the identical crop, namely, sugar cane, is produced on all but two of the agricultural soils represented in the table, and hence the demand upon the soils for potassium is similar.

Effect of Cropping on the Distribution of Available Potassium in the Soil Profile:

At Ewa, Aiea, Waimanalo and Poamoho profile samples were obtained from soils in uncropped as well as cropped areas. From these it should be possible to obtain some indication of the effect of agricultural practices upon the vertical distribution of potassium in the soil. Considering first the residual, virgin Ewa soil 43–34 (Fig. 10), it will be seen that the distribution of potassium is not dissimilar to that in some of the cropped soils of this plantation, particularly is it not unlike, in major respects, that in the residual cropped soil No. 43–10 (Fig. 3) with which it can most justifiably be compared. At Waimanalo, also the virgin and the two cropped soils sampled possessed very similar distribution patterns (Figs. 15–17) although the quantities of potassium in the soils were different. Similar results were obtained in the Aiea soils. At Poamoho, on the other hand, the distribution of potassium in soil cropped to Napier grass differed sharply from that in the soil of an adjacent uncropped area, as may be seen by a comparison of Figs. 23 and 24. It will be noted that the decrease in potassium with depth in the uncropped soil is pronounced, whereas that in the corresponding cropped soil is relatively very slight, potassium in the latter decreasing only from 120 pounds K_2O per acre in the 0-to-6-inch horizon to a minimum of 85 pounds in the 18-to-24-inch horizon. The reason cropping has apparently affected the distribution of potassium in the Poamoho soils and not in the other soils which have been considered will become more apparent in the following section.

Discussion

Although too little is known regarding the factors determining the distribution of exchangeable potassium in the soil to explain completely the observed results, yet

certain processes may be pointed out, the effects of which appear to be in accord with the facts. Let us consider first an uncropped soil upon which some sort of vegetation is growing. The roots of the plants will absorb potassium from the soil to depths depending upon the type of plant and other factors, and from the roots most of the potassium will be transported to the aerial portions of the plant. Much of this potassium, either through the death of the plant or through the sloughing of dead tissues, will subsequently be deposited upon the surface of the soil, whence leaching will gradually carry it downward. In this manner vegetation tends to maintain a diminishing downward potassium gradient in the upper horizons of the soil.

The situation differs in the case of sugar cane field soils in that part of the potassium in the above-ground portions of the plant is removed from the field at harvest. The equivalent of this potassium may or may not be returned to the soil through fertilization. The substantial nature of the movement of potassium from the root zone of sugar cane field soils to the surface may be seen from the following: It was found by the writer (1) that, in the course of the production of a 100-ton crop of sugar cane, in the neighborhood of 550 pounds of K_2O per acre were transferred from the soil to the aerial portions of the plant. Of this amount of potassium approximately 250 pounds were present in the millable cane and were removed from the field at harvest. The remainder of the potassium, *i.e.,* that contained in the tops, dead leaves and dead cane amounted to 300 pounds* and was returned to the surface of the soil through the processes of burning, leaching and microorganic decomposition. In addition to potassium thus brought to the soil surface during each crop, further quantities of potassium, as has been noted, are frequently applied to the soil as fertilizer. The continuous operation of this "cycle" appears to account for the observed diminishing potassium gradients in the upper horizons of the sugar cane soils studied.

It was pointed out in the preceding section that potassium decreased only slightly with depth in the Napier grass soil at Poamoho (Fig. 23). The same is true also of a University Farm, Manoa soil (Fig. 4) which is similarly devoted to the continuous production of Napier grass. The distribution patterns for potassium in these soils thus contrast strikingly with those in the virgin and sugar cane soils. The reason for this difference appears to be as follows: The two factors to which have been ascribed the observed diminishing potassium gradients in the upper horizons of the virgin and sugar cane soils are almost wholly lacking in the case of the Napier grass soils. In the first place, under Napier grass culture as practiced in these areas, practically no plant residues are returned to the surface of the soil, the crops being harvested at the age of about four months and while nearly all of the leaves are still green and attached to the stem. In the second place no potassium has been applied to the Poamoho soil as fertilizer in recent years and only 100 pounds of K_2O per acre to the Manoa soil since 1939. As a result there has been little or no building up of potassium in the surface layers of these soils. It seems logical to conclude, therefore, that the nature of the crop and the associated cultural practices are responsible for the low potassium gradients in the Napier grass soils. The same factors appear to account for the fact that the distribution of potassium in the Poamoho

* Where sugar cane is harvested by machines, proportionately smaller quantities of the potassium taken up by the crop are returned to the soil.

soil was much more affected by cropping than was the case in the sugar cane soils.

It was shown by Fireman and Bodman (5) and by the writer (2) that when non-vegetative soils are leached with distilled water a potassium gradient *increasing* with depth is established. The effects of vegetation, in the absence of appreciable leaching, and of leaching, in the absence of vegetation, are thus to produce potassium gradients which are opposite in direction. Since potassium in the soils studied decreases with depth in the soil, it must be concluded that under the conditions of rainfall and irrigation encountered in this study the direction of the gradient in the soil is determined by the action of the vegetation rather than of leaching.

Significance of the Results With Respect to Soil Sampling

If the chemical and positional availabilities of exchangeable potassium to depths of several feet be assumed, then it is apparent that the ordinary techniques of soil sampling, involving only the surface layer of the soil, result in a very incomplete picture of the quantities of potassium at the disposal of the crop. Manifestly, it is not feasible in ordinary soil-testing work to attempt the laborious sampling methods employed in this study of the soil profile. It would seem well to bear in mind, however, the limitations of surface sampling and to weigh the results obtained therefrom accordingly.

Summary

A study was made of the distribution of exchangeable potassium in Oahu soil profiles. The results may be summarized as follows:

Potassium in the profiles was found to be distributed according to one of the three following patterns:

1. Potassium decreased with depth to the bottom of the section of the profile examined.
2. Potassium decreased downward to a point within the section and thereafter remained constant.
3. Potassium decreased with depth to about 1½ to 2 feet and increased with greater depth.

The total quantities of exchangeable potassium present in the 0-to-3-foot zone ranged from 335 to 5,635 pounds, and in the 0-to-4-foot zone from 450 to 7,180 pounds of K_2O per acre, respectively.

It is apparent that sampling techniques which involve only the surface layers of the soil result in very incomplete pictures of the quantities of potassium available to deep-rooted plants such as sugar cane.

The production of sugar cane does not appear to have substantially altered the natural vertical distribution pattern of exchangeable potassium in the soil.

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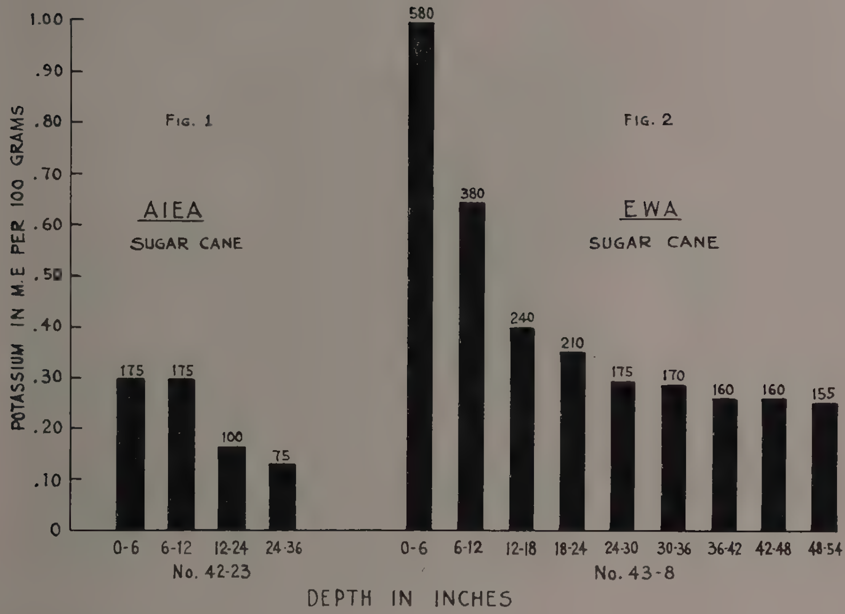
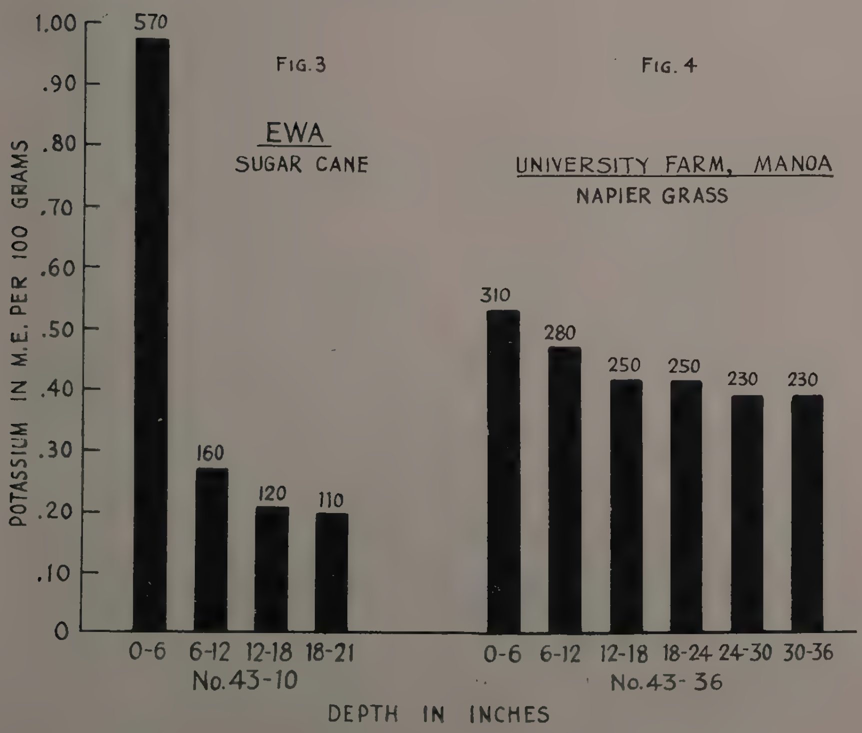

1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
POTASSIUM IN M.E PER 100 GRAMS
FIG. 1
AIEA
SUGAR CANE
175
175
100
75
0-6 6-12 12-24 24-36
No. 42-23
FIG. 2
EWA
SUGAR CANE
580
380
240
210
175
170
160
160
155
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48 48-54
No. 43-8
DEPTH IN INCHES


1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
POTASSIUM IN M.E. PER 100 GRAMS
FIG. 3
EWA
SUGAR CANE
570
160
120
110
0-6 6-12 12-18 18-21
No. 43-10
FIG. 4
UNIVERSITY FARM, MANOA
NAPIER GRASS
310
280
250
250
230
230
0-6 6-12 12-18 18-24 24-30 30-36
No. 43-36
DEPTH IN INCHES

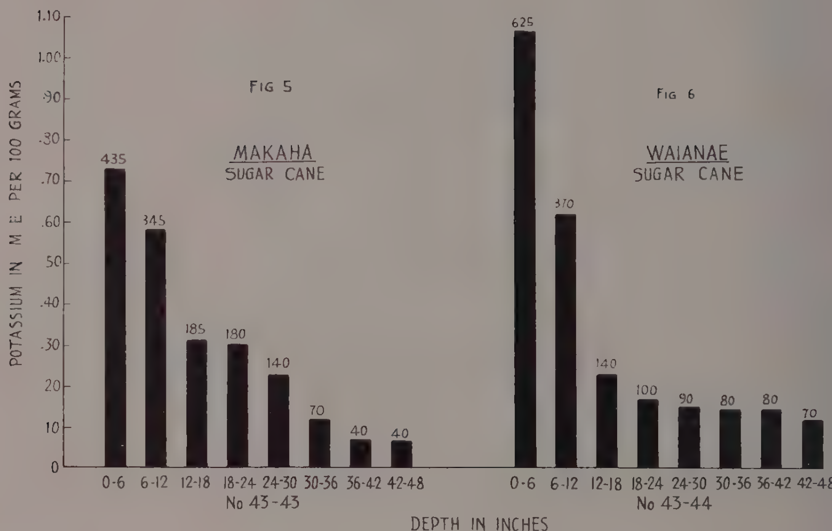


Fig 5
MAKAHA
SUGAR CANE
Fig 6
WAIANAE
SUGAR CANE
POTASSIUM IN M E PER 100 GRAMS
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
435
345
185
180
140
70
40
40
625
370
140
100
90
80
80
70
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48
No 43-43
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48
No 43-44
DEPTH IN INCHES

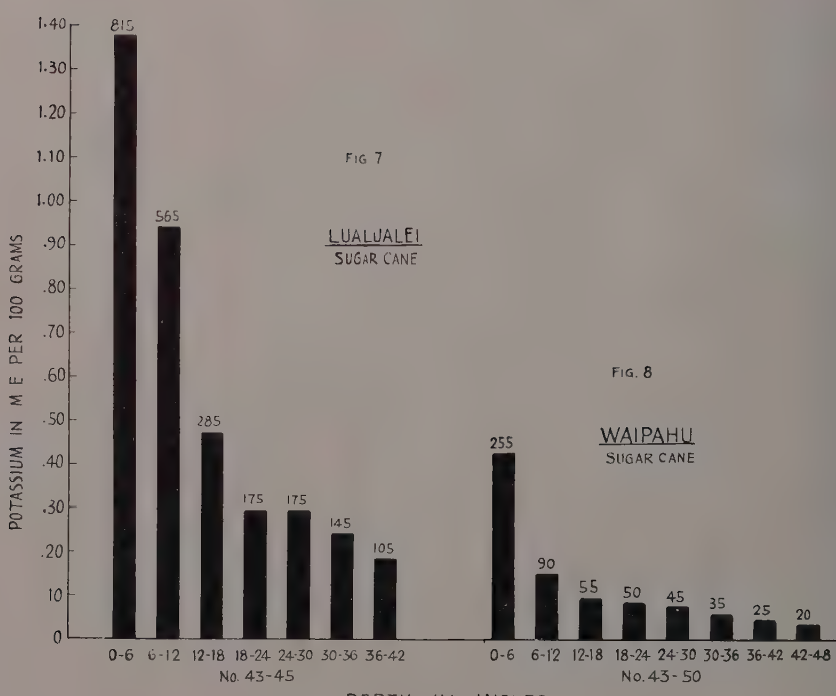


Fig 7
LUALUALEI
SUGAR CANE
Fig. 8
WAIPAHU
SUGAR CANE
POTASSIUM IN M E PER 100 GRAMS
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
815
565
285
175
175
145
105
255
90
55
50
45
35
25
20
0-6 6-12 12-18 18-24 24-30 30-36 36-42
No. 43-45
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48
No. 43-50
DEPTH IN INCHES

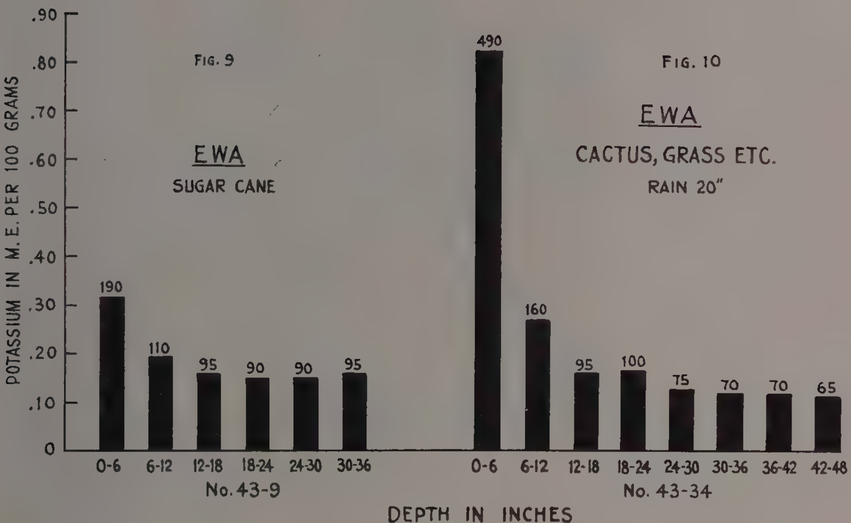


FIG. 9
EWA
SUGAR CANE
FIG. 10
EWA
CACTUS, GRASS ETC.
RAIN 20"
POTASSIUM IN M.E. PER 100 GRAMS
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
190
110
95
90
90
95
490
160
95
100
75
70
70
65
0-6
6-12
12-18
18-24
24-30
30-36
No. 43-9
0-6
6-12
12-18
18-24
24-30
30-36
36-42
42-48
No. 43-34
DEPTH IN INCHES

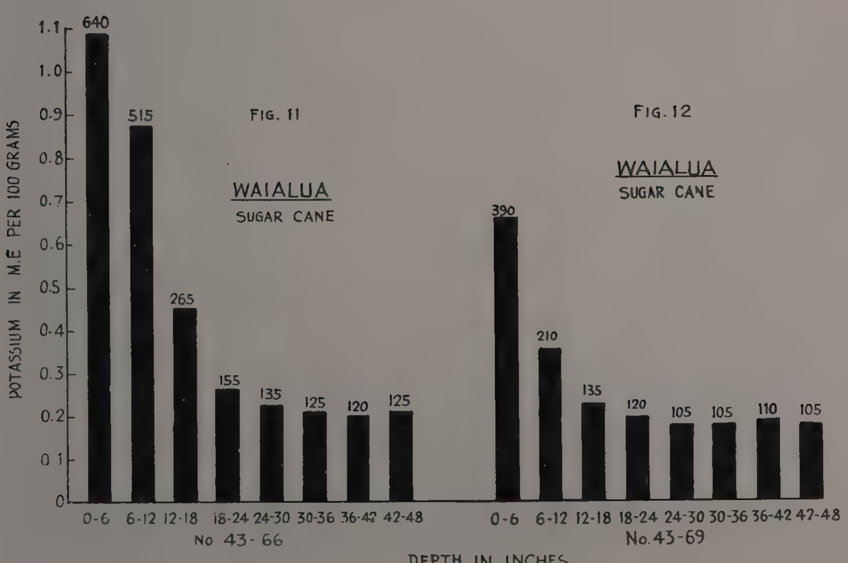


FIG. 11
WAIALUA
SUGAR CANE
FIG. 12
WAIALUA
SUGAR CANE
POTASSIUM IN M.E PER 100 GRAMS
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
640
515
265
155
135
125
120
125
390
210
135
120
105
105
110
105
0-6
6-12
12-18
18-24
24-30
30-36
36-42
42-48
No 43-66
0-6
6-12
12-18
18-24
24-30
30-36
36-42
42-48
No. 43-69
DEPTH IN INCHES

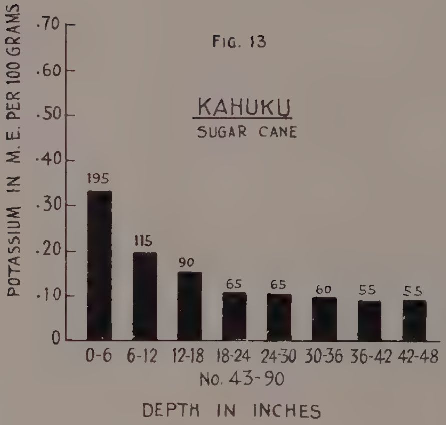


FIG. 13
KAHUKU
SUGAR CANE
POTASSIUM IN M.E. PER 100 GRAMS
.70
.60
.50
.40
.30
.20
.10
0
195
115
90
65
65
60
55
55
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48
No. 43-90
DEPTH IN INCHES

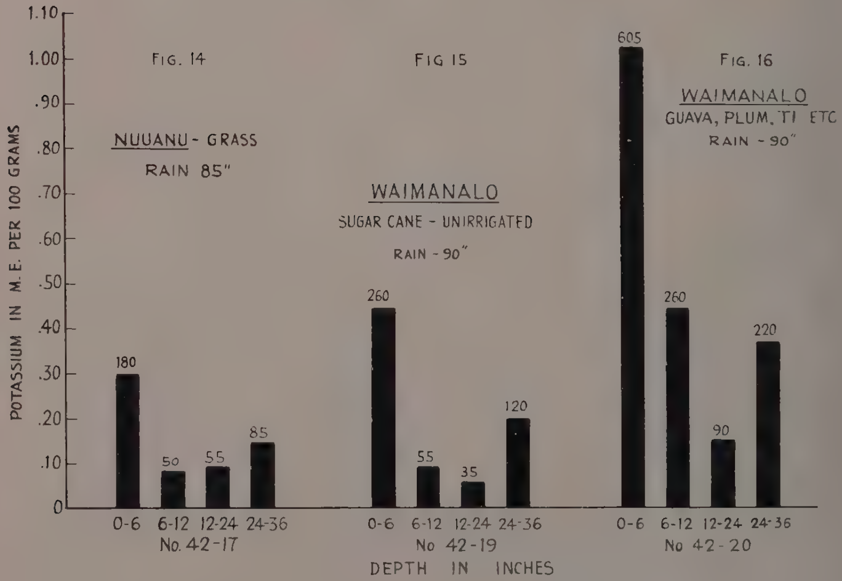
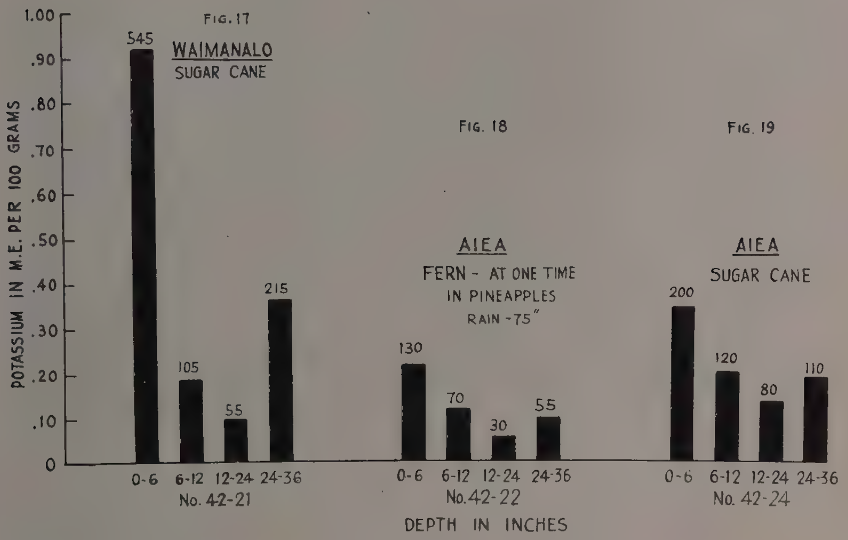
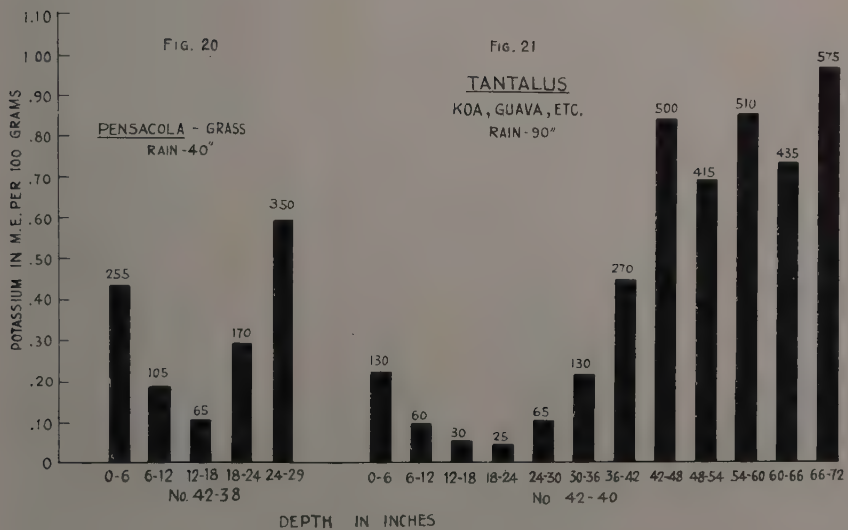


FIG. 14
NUUANU - GRASS
RAIN 85"
FIG 15
WAIMANALO
SUGAR CANE - UNIRRIGATED
RAIN - 90"
FIG. 16
WAIMANALO
GUAVA, PLUM, TI ETC
RAIN - 90"
POTASSIUM IN M.E. PER 100 GRAMS
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
180
50
55
85
260
55
35
120
605
260
90
220
0-6 6-12 12-24 24-36
No. 42-17
0-6 6-12 12-24 24-36
No 42-19
0-6 6-12 12-24 24-36
No 42-20
DEPTH IN INCHES



1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
POTASSIUM IN M.E. PER 100 GRAMS
FIG. 17
WAIMANALO
SUGAR CANE
545
105
55
215
0-6 6-12 12-24 24-36
No. 42-21
FIG. 18
AIEA
FERN - AT ONE TIME
IN PINEAPPLES
RAIN - 75"
130
70
30
55
0-6 6-12 12-24 24-36
No. 42-22
FIG. 19
AIEA
SUGAR CANE
200
120
80
110
0-6 6-12 12-24 24-36
No. 42-24
DEPTH IN INCHES



1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
POTASSIUM IN M.E. PER 100 GRAMS
FIG. 20
PENSACOLA - GRASS
RAIN - 40"
255
105
65
170
350
0-6 6-12 12-18 18-24 24-29
No. 42-38
FIG. 21
TANTALUS
KOA, GUAVA, ETC.
RAIN - 90"
130
60
30
25
65
130
270
500
415
510
435
575
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48 48-54 54-60 60-66 66-72
No 42-40
DEPTH IN INCHES

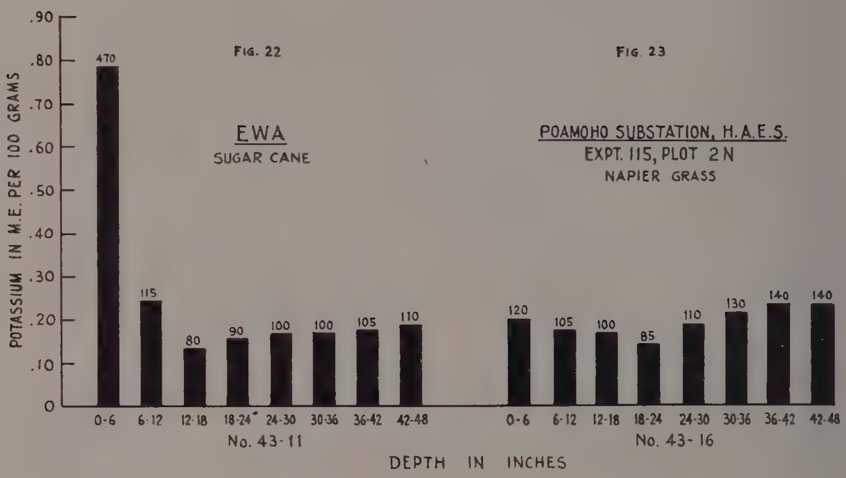


FIG. 22
EWA
SUGAR CANE
FIG. 23
POAMOHO SUBSTATION, H.A.E.S.
EXPT. 115, PLOT 2 N
NAPIER GRASS
POTASSIUM IN M.E. PER 100 GRAMS
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
470
115
80
90
100
100
105
110
120
105
100
85
110
130
140
140
0-6
6-12
12-18
18-24
24-30
30-36
36-42
42-48
No. 43-11
0-6
6-12
12-18
18-24
24-30
30-36
36-42
42-48
No. 43-16
DEPTH IN INCHES

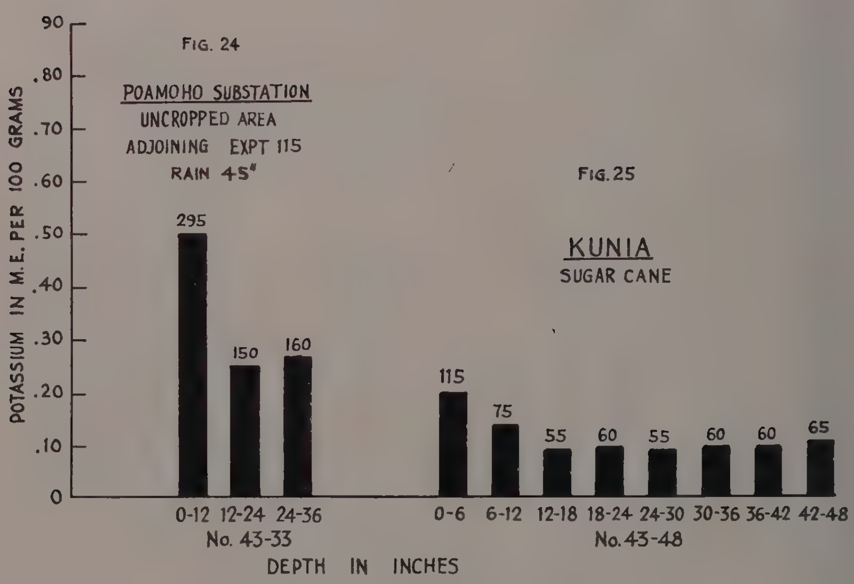
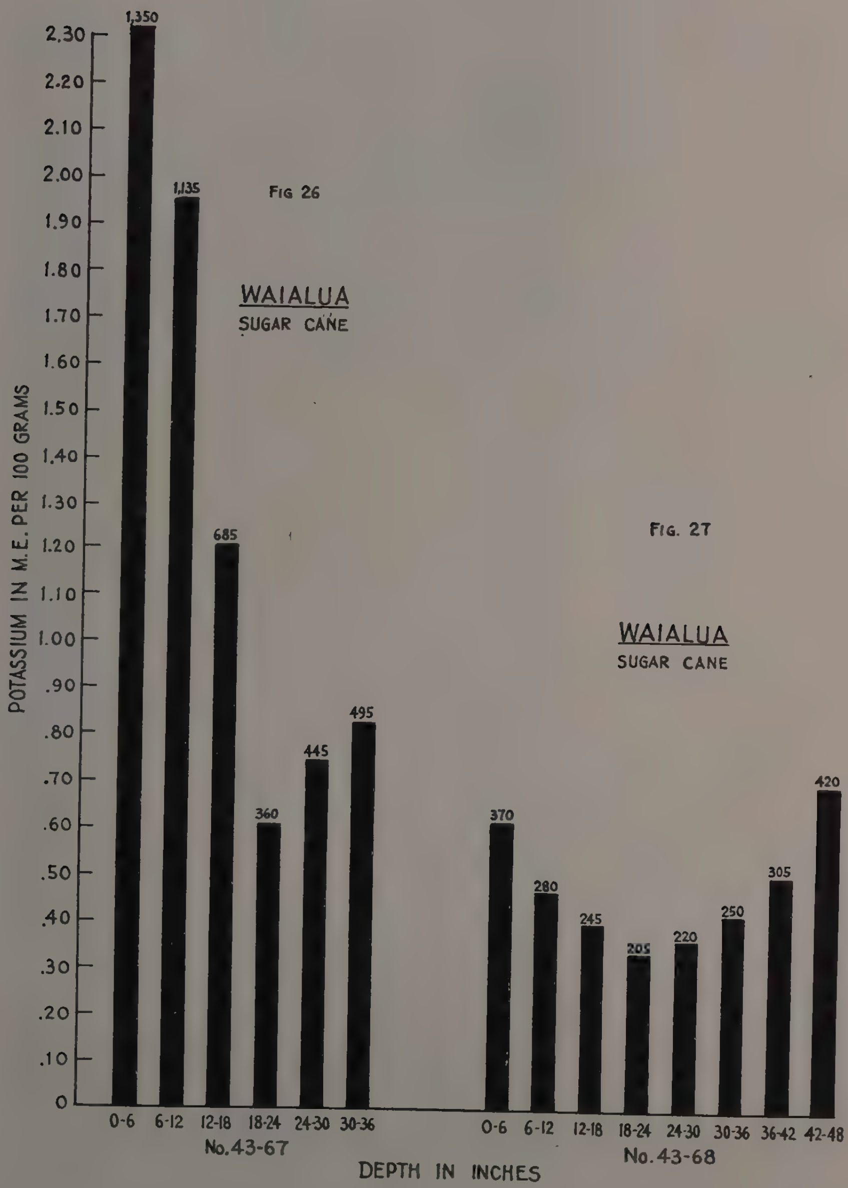


FIG. 24
POAMOHO SUBSTATION
UNCROPPED AREA
ADJOINING EXPT 115
RAIN 45"
FIG. 25
KUNIA
SUGAR CANE
POTASSIUM IN M.E. PER 100 GRAMS
90
.80
.70
.60
.50
.40
.30
.20
.10
0
295
150
160
115
75
55
60
55
60
60
65
0-12
12-24
24-36
No. 43-33
0-6
6-12
12-18
18-24
24-30
30-36
36-42
42-48
No. 43-48
DEPTH IN INCHES


1,350
1,135
685
360
445
495
370
280
245
205
220
250
305
420
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
POTASSIUM IN M.E. PER 100 GRAMS
FIG 26
WAIALUA
SUGAR CANE
FIG. 27
WAIALUA
SUGAR CANE
0-6
6-12
12-18
18-24
24-30
30-36
No. 43-67
0-6
6-12
12-18
18-24
24-30
30-36
36-42
42-48
No. 43-68
DEPTH IN INCHES

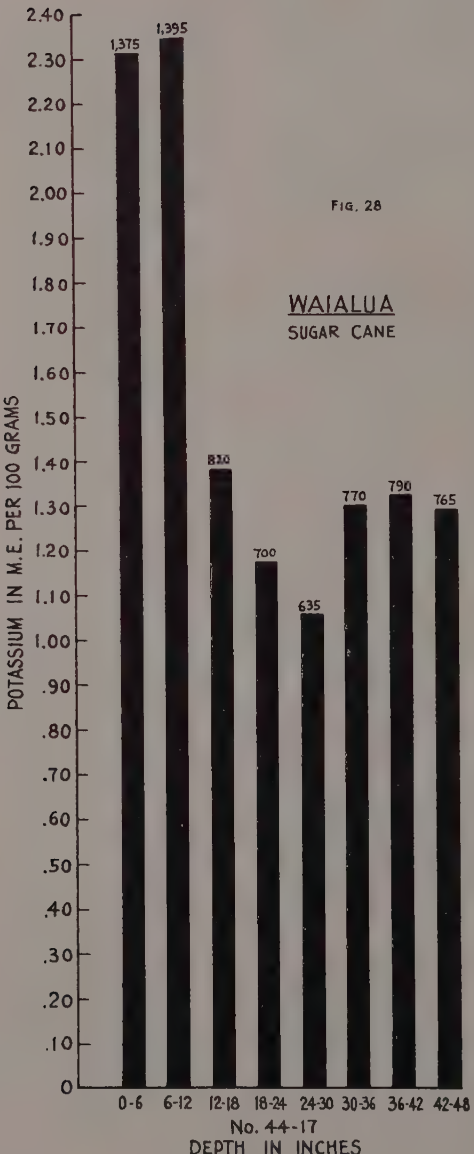


FIG. 28

WAIALUA
SUGAR CANE

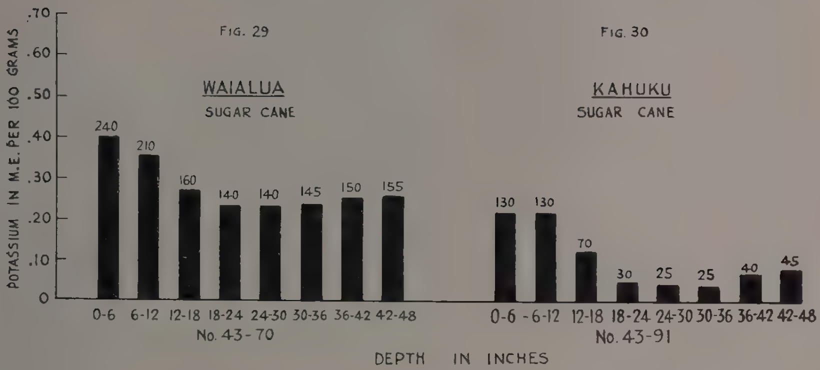


Fig. 29
WAIALUA
SUGAR CANE
Fig. 30
KAHUKU
SUGAR CANE
POTASSIUM IN M.E. PER 100 GRAMS
.70
.60
.50
.40
.30
.20
.10
0
240
210
160
140
140
145
150
155
130
130
70
30
25
25
40
45
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48
No. 43-70
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48
No. 43-91
DEPTH IN INCHES

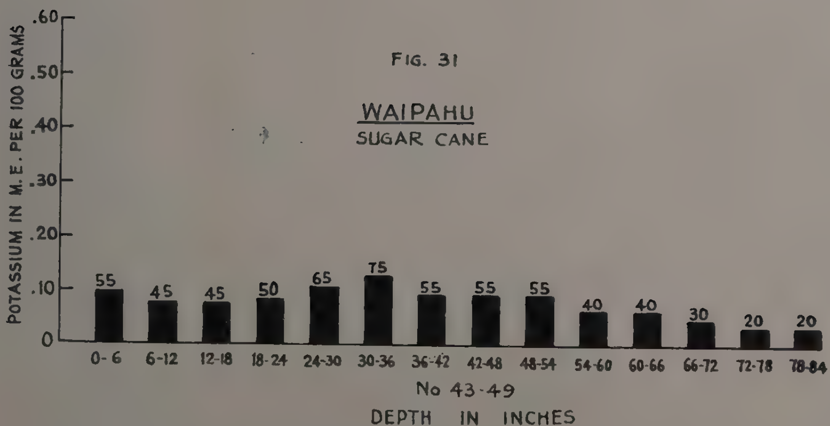


Fig. 31
WAIPAHU
SUGAR CANE
POTASSIUM IN M.E. PER 100 GRAMS
.60
.50
.40
.30
.20
.10
0
55
45
45
50
65
75
55
55
55
40
40
30
20
20
0-6 6-12 12-18 18-24 24-30 30-36 36-42 42-48 48-54 54-60 60-66 66-72 72-78 78-84
No 43-49
DEPTH IN INCHES

A Search for Guidance in the Nitrogen Fertilization of the Sugar Cane Crop

Part II—The First Ratoon Crop

By R. J. Borden

A second series of measurements and analyses which have now been made on representative samples of 32–8560 cane taken from the first ratoon crop of Waipio Experiment 108 ATN has supplied further evidence in our search for guidance in the nitrogen fertilization of the sugar cane crop. Additional supplementary information about the nature of the development of this cane variety and of its composition at progressive growth stages has been accumulated and studied, and the many interesting relationships found have added much to our general knowledge. As yet, however, we have not been wholly successful in identifying definite levels or percentages of nitrogen or of other components which can be depended upon for assurance that their adjustment, by means of additional nitrogen applications, will give us the desired results, i.e., more sugar. But our search continues!

Contents

Introduction

In Part I of this investigation we reported* many measurements and analyses made from the 32–8560 plant cane of a nitrogen experiment grown at Waipio and sampled periodically during its development. In this Part II we shall present many similar data obtained from the first ratoon crop grown on the identical area of the plant crop, and in general following a similar plan and procedure; major differences will be pointed out as the discussion proceeds.

The Plan and Procedure

1. *The Plan:*

The experimental area has previously been described. After the harvest of the plant crop the area was cleaned up, the lines reshaped and the ditches repaired. Irrigation followed immediately and the crop was officially started on May 25, 1942; this was in contrast to the slightly later start (August 1) which the plant crop had. All blank spaces in the cane rows were replanted with good 32–8560 seed pieces within the following 10 days.

The specific fertilizers for this ratoon were applied by hand according to the following plan:

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* Borden, R. J., 1942. A search for guidance in the nitrogen fertilization of the sugar cane crop. Part I—The plant crop. The Hawaiian Planters' Record, 46: 191–238.

Plot identity	No. of plots	Appl. no. 1 7/1/42 Lbs. N	Appl. no. 2 9/10/42 Lbs. N	Lbs. K_2O	Appl. no. 3 10/23/42 Lbs. N	Appl. no 4 4/27/43 Lbs. N	Total per acre Lbs. N	Lbs. P_2O_5	Lbs. K_2O
A.........	8	40	60	100	0	0	100	0	100
B.........	8	40	60	100	0	60	160	0	100
C.........	8	40	60	100	60	0	160	0	100
D.........	8	40	60	100	60	60	220	0	100

In addition, the same 3 "X" plots which had received no nitrogen during the plant crop were again included and again received no nitrogen.

When the crop was two months old ten sampling stations were carefully chosen and pinned out in each plot. Each station consisted of a solid stand in a five-foot row of cane containing no replant and enjoying no advantage from its proximity to the slower-developing replant. It was from one of these stations in each plot that all cane stalks were cut to provide the cane samples in the periodic harvests which followed at the ages of 3½, 5½, 7½, 8½, 9½, 10½, 11½, 14½, 17½ and 20½ months.

Irrigation intervals close to 250 day-degrees were maintained until November 27, 1943 when irrigation was stopped. Total rainfall between this date and final harvest of the field amounted to 7.6 inches, with another 2.0 inches falling while this harvest was in progress.

2. *Observations and Comments at Periodic Harvests:*

At first preharvest at 3½ months: (1) The ratoon crop had made rapid growth from its initial 40 pounds of nitrogen and had already produced some fair-sized stalks. Tillering had been heavy and the selected sampling areas were carrying better than ten stalks* per foot of row. Great variation in individual stalk development was apparent and the 32 specific five-foot sampling areas, which had been previously chosen for their similarity of stand, now showed tremendous growth differences; in total green weight, these actually ranged from 12.8 to 57.8 pounds or equivalents of from 11 to 51 tons per acre. (2) The replant was slow and much was in danger of being handicapped by the adjacent ratoon growth. (3) A definitely lighter green leaf color and an inferior growth was apparent on the "X" or "no N" plots. (4) No evidence of a residual effect from the plant crop's treatments was to be seen.

At second preharvest at 5½ months: (1) The cane except in the "no N" plots had now "covered in," some dry-leaf cane stalk had been formed, and many small shoots were dying off. (2) Leaf color was exceptionally good, *i.e.,* a dark green, and both leaves and stalks were extremely succulent. (3) The growth of primary stalks now appeared more uniform.

At third preharvest at 7½ months: (1) As a result of the heavy rains in December many stalks had already "gone down." (2) A few suckers had now made their first appearance. (3) The stand was now approximately five stalks per foot of row, and there were very few live stalks without some millable cane at this harvest.

At fourth harvest at 8½ months: (1) Most of the canes were now recumbent and the first record of dead primaries was made. (2) Suckers were more numerous on the plots which had received the larger nitrogen application. (3) The cane was still very succulent and had good leaf color; it still lacked creditable sweetness.

* Showing at least three nodes.

At fifth harvest at 9½ months: (1) Primary stalks which had not yet made millable cane were now dead, and there were now only about three to four stalks with millable cane per foot of row. (2) Suckers were increasing in numbers and growing rapidly; some had even developed a few feet of millable cane. (3) Millable canes were now definitely sweet. (4) Leaf color was still excellent, although that of cane which had received only 100 pounds of nitrogen was lighter than that of the more heavily (160 pounds) fertilized cane.

At sixth harvest at 10½ months: (1) The difference in leaf color between the 100 and 160 pounds N treatments was quite pronounced. (2) Suckers continued to increase and were definitely more numerous on plots of the higher nitrogen treatment where there were also more dead primary stalks.

At seventh harvest at 11½ months: (1) All plots now show a large number of suckers, both more and farther advanced in development than in the previous harvest; the tops of some of these suckers have already been shaded out and are dead. (2) Variation between replicate samples is again very great.

At eighth harvest at 14½ months: (1) The number of live and of dead primary stalks with millable cane has not changed much since the 5th harvest, but the suckers have steadily increased until they now amount to nearly 40 per cent of the total number of millable stalks; many of these millable suckers are of large diameter, and their dry-leaf section contains much sugar (Brix at 20).

At ninth harvest at 17½ months: (1) An idea of the great variation between replicates at this harvest may be gained from the following:

Treatment	No. of replicates	Range in number of stalks within 5 feet of cane row: Primaries	Suckers	Dead	Range in equivalent tons per acre yields of millable cane (net area basis)
X	3	9–17	3–10	0	37–82
A	8	11–27	3–13	1–6	74–162
B	8	8–30	4–23	2–11	79–293
C	8	7–20	5–23	1–14	82–193
D	8	9–21	4–17	3–11	79–202

Note: The outstanding "5-foot of row" cane sample came from Plot 34B at 17½ months. It included 22 primary stalks, 23 suckers (only 2 of which were without millable cane) and 8 stalks with dead tops; a total of 53 stalks or 10.6 per foot of row.

(2) The tops were generally small and the leaves badly shredded. (3) Except in the "X" plots there were many dead primary stalks, most of which had developed "splits" some time previous.

At tenth harvest at 20½ months: (1) The tops especially of primary stalks were all quite small. (2) The great variation in replicates continues. (3) Heavy suckering was found especially in the high-nitrogen "D" plots. (4) There were many dead stalks including some suckers which had made several feet of millable cane.

3. *Experimental Procedure:*

The monthly collection of soil samples and of leaf-punch samples for subsequent nitrogen analyses followed the same procedure that was used in the plant crop. This was also true of the collection and preparation of the ten preharvest cane samples so that they would again be truly representative of the crop in their respective field plots.

Records of total green weight and of millable cane were secured at each prehar-

vest and are reported on their equivalent tons per acre (net area) basis. At the same time, a complete census was made of all stalks cut from each sampling station, and on the basis of this census, duplicate cane samples were made up for further processing. One of these samples after being topped was milled in the Waipio Cuban A mill and the crusher juice therefrom analyzed for nitrogen and yield of commercial sugar. The duplicate cane sample (but not topped) was prepared for laboratory analyses. These laboratory samples of the total green weight from each plot were analyzed by standard chemical methods for total nitrogen, phosphoric acid, potash, moisture, reducing sugars, sucrose, and fiber. Chlorophyll determinations and studies of leaf-sheath composition were not included in this year's study.

All measurements and analytical data from the eight replicates of the four treatments which received nitrogen fertilizer were again subjected to statistical study by the "analysis of variance" to determine what degree of reliability might be placed on differences due to treatment.

4. *Monthly Soil Analyses (Fig. 1):*

Soil samples were taken monthly to a depth of 12 inches in the area midway between the rows of cane from a series of "no-nitrogen" and "high nitrogen" plots. These were tested immediately by our modified Mitscherlich test and the results

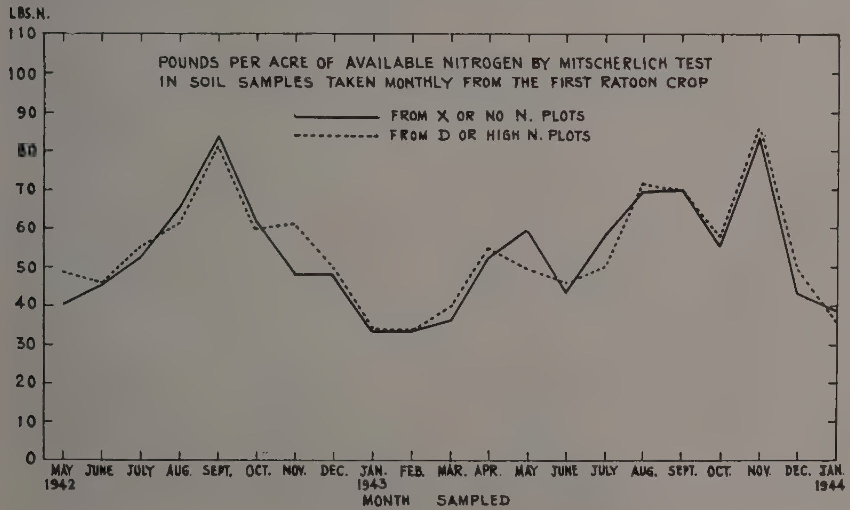

Fig. 1.

which are shown graphically in Fig. 1 indicate the status of the available soil nitrogen content in this experimental area while the ratoon crop was being grown.

The similarity between the two curves in Fig. 1 offers convincing evidence that the effects are natural soil effects and not an influence of applied nitrogen fertilizer. The first sample from this ratoon crop showed a nitrogen availability which was quite comparable to that secured from the last sample which had been taken from the preceding crop. Thereafter there was an increase in the available nitrogen supply until the cane was almost covered in and its roots had spread laterally well into the row middles. At this time, there began a rapid falling off in the amount of soil

nitrogen with a low point of 30-35 pounds per acre being reached in January when the crop was 7½ months old. Unlike the corresponding result from the plant crop however, this low-nitrogen level was not maintained through the rest of the growing period but it started to increase with the advent of spring, and with a few exceptions continued its upward trend for six or eight months more.

The reasons for this increase in available nitrogen from the soil's natural supply are not known. It occurred right after the cane had "gone down" and again exposed some of the surface soil areas to more air and sun, for the trash blanket at this time was not extra heavy. But whatever the reason, the fact is clear that soil nitrogen did contribute something to this ratoon crop during its second year of growth—a contribution that was not found as definitely during a corresponding period in the plant crop from the same area.

Treatment Effects

1. *Their Reliability:*

In spite of our initial efforts to select a series of comparable cane sampling stations in the field plots, subsequent natural variations in growth largely offset our good intentions.

Thus the analysis of variance has again indicated some high residual errors in cane weights and calculations based thereon, and our eight replicates have been generally inadequate in establishing reliable significance to many quite large treatment differences at the periodic harvests. However, although many large differences between treatment averages are shown with a tag of "non significance," a careful rationalization of the data will often give a logical interpretation that may at least be tentatively accepted.

In Table I we have summarized the coefficients of variation (based on the residual error variance) for the different measurements and analyses that were made at each harvest. They offer some interesting evidence: for instance, the coefficients of variation for all measurements under "tons per acre" and "pounds per acre" are high, and indicate the extreme variability in weights even in carefully harvested replicates of sugar cane field samples. The variation in the composition of these variable cane samples is, however, considerably lower for most of the measurements made. Thus the very low coefficients of variation for per cent moisture indicate great uniformity in this component of the sugar cane crop. The C. V.'s for fiber also indicate quite a satisfactory uniformity. On the other hand there is evidence of wide variation in the percentage of reducing sugars between the replicate cane samples; this is especially noticeable at the 5th, 6th, and 7th harvests when the stalk population was changing and sucker growth was booming. In the per cent sucrose and per cent total sugars, the replicates show a very fair similarity especially after the crop has become well established. For their major nutrient composition (per cent N, P_2O_5, K_2O) the replicated total cane samples show a variation which might be a reflection of the age differences in their stalk populations—thus an indirect effect from the wide variation in the total cane weights.

The replicate analyses for per cent N from the crusher juice samples were extremely variable at every harvest, and it is quite apparent that this analysis is less dependable for comparative purposes than the corresponding N analysis made from the total cane sample.

The generally low coefficients of variation for per cent N in the leaf-punch sam-

ples speak well for the uniformity of the plant material from which these samples were taken. This makes it apparent that it will be easier to duplicate the nitrogen analyses from properly taken leaf-punch samples than from either total green weight or crusher juices.

TABLE I

COEFFICIENTS OF VARIATION

Measurements	Harvest No.:	1	2	3	4	5	6	7	8	9	10
	Month:	Sept.	Nov.	Jan.	Feb.	Mar.	Apr.	May	Aug.	Nov.	Feb.
	Age (mos.):	3½	5½	7½	8½	9½	10½	11½	14½	17½	20½
In tons per acre:											
For total green weight		35.5	24.1	16.7	22.9	22.5	19.7	38.8	22.1	33.2	31.2
For total dry weight..		33.2	25.9	17.8	25.0	25.1	19.9	38.2	22.4	33.3	32.3
For total red. sugars .		45.2	27.4	20.7	21.9	29.5	34.1	52.4	28.4	42.8	47.4
For total sucrose		43.8	30.7	21.9	28.4	24.9	19.5	39.4	22.6	33.3	32.0
For total sugars......		44.5	28.6	20.0	27.3	24.5	19.6	39.5	22.2	32.5	31.7
For millable cane		44.6	26.9	17.2	23.9	22.3	19.0	39.3	22.7	34.0	32.7
For commercial sugar .		250.0	59.7	29.5	36.3	26.3	23.1	39.0	23.1	34.1	34.4
In pounds per acre:											
For P_2O_5 in total cane		26.2	23.6	21.6	29.2	26.8	23.7	40.5	23.9	35.5	34.6
For K_2O in total cane		37.3	23.3	25.3	26.6	22.3	27.0	40.8	19.8	30.8	33.1
For N in total cane...		29.2	26.4	21.6	22.5	25.9	22.2	37.2	22.6	33.3	37.9
In total cane harvested:											
For % tops..........		12.0	12.9	11.7	15.8	7.5	13.1	10.7	10.8	14.8	14.7
For % moisture......		1.3	1.1	1.1	1.6	1.5	1.4	1.9	1.7	1.4	2.1
For % fiber		6.9	5.5	4.6	7.0	6.6	6.3	6.5	4.6	5.5	6.1
For % red. sugars....		17.0	16.6	13.9	17.8	30.6	25.4	31.3	18.2	21.4	38.9
For % sucrose		14.9	8.6	11.7	8.6	4.9	7.9	5.6	6.1	4.1	6.1
For % total sugars...		4.1	7.9	9.6	7.0	4.9	7.2	5.2	5.0	6.4	5.5
For % P_2O_5		12.9	9.3	11.5	13.6	10.9	8.5	15.5	10.4	10.1	13.4
For % K_2O..........		13.6	10.1	15.6	19.5	15.1	16.5	15.6	13.9	9.8	13.7
For % N............		8.8	13.1	9.6	11.3	12.1	8.8	12.9	12.5	10.4	15.8
In % N in leaf-punches..		4.0	2.1	1.1	1.5	1.4	2.3	2.3	3.5	5.2	4.8
In % N in crusher juice..		21.4	29.2	20.8	20.7	32.0	34.6	21.7	23.1	21.4	20.0
In yield % cane.........		20.0	47.1	19.5	17.0	8.5	13.1	8.7	14.3	12.5	10.2

2. *On the Stalk Population (Fig 2):*

A census of the stalk population which was made at each preharvest gives an interesting picture of the changes that took place in the composition of the crop as it developed and shows some rather definite influences of the nitrogen fertilizations, particularly those which were made in April to cane which was 11 months old. Especially notable is the greater increase in the number of suckers with millable stalk at 14½ and 17½ months that resulted when the April nitrogen application was made to cane which had received only 100 pounds of N previously, than to cane which had already received 160 pounds. This influence is quite clearly shown in the two upper graphs in Fig. 2 (compare B over A with D over C), and it possibly indicates an influence from the timing of the nitrogen fertilization, because the earlier or October application did not give us the same clear-cut differences between Treatments C and A that the later or April application made between B and A.

The lower graph in Fig. 2 shows that the large applications of nitrogen have resulted in more stalks with dead tops at 17½ and 20½ months. The actual numbers at the last harvest seem large, averaging approximately one-third of the total number of canes which had made millable stalk. Some of them had been dead and

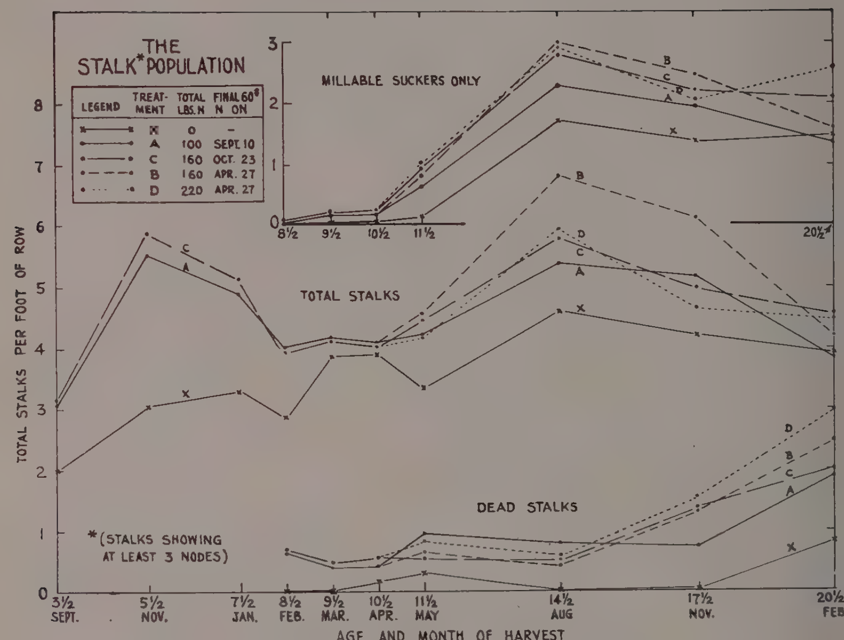

Fig. 2.

dry for many months, whereas others were in various earlier stages of decomposition.

It should be apparent that these two factors—number of suckers with more or less millable cane, and of dead or dying stalks at harvest—can have a considerable effect on the crop's crusher juice quality, and since both of them are influenced by the nitrogen fertilization, a large part of the well-recognized effect of nitrogen on crusher juices may be due to its direct influence on the stalk population.

3. *On Total Green Weights (Fig. 3) (Table 1 in Appendix):*

Yields of total green weight from this first ratoon crop were again influenced by the nitrogen fertilizations. The "C" plots which received an additional 60-pound application of N late in October were rather slow to respond during the winter but by spring they jumped ahead and thereafter maintained their increases over the "A" plots which had been supplied with only the basic amount of 100 pounds. The "B" plots with their extra 60 pounds of N applied late in April immediately picked up weight and held a big lead over the "A" plots. A second additional 60-pound application made in April to create Treatment "D" also increased yields over Treatment "C's" total of 160 pounds but it is very doubtful whether Treatment "D" which received a total of 220 pounds of N produced any more vegetative growth than Treatment "B" which had been given only 160 pounds.

When discussing the plant crop we called attention to the nature of the production of total green weight, i.e., its rapid increase up to the time when it was 5½ months old, its apparent slowing up when only 7½–9½ months old, and its accelerated rate of production thereafter until it was dried off for harvesting. For this

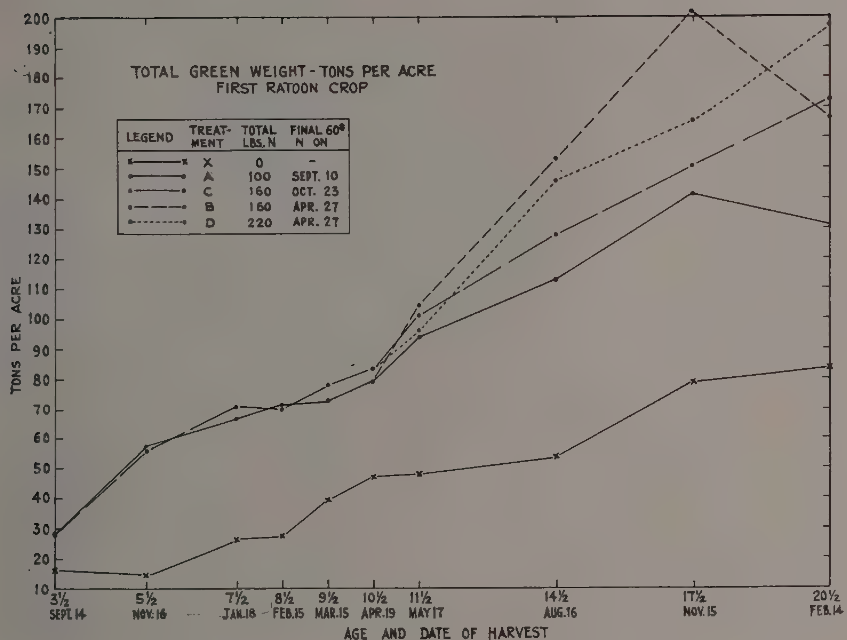

Fig. 3.

ratoon crop, we find a similarity with the plant crop in its vegetative development, even though the average effect occurred under slightly different seasonal conditions. If we had not already noted the slowing up in the plant crop between 7½ and 9½ months during March-May, we might imply that the slow up of the ratoons at this age in January-March was due to its winter check in growth, but it is now thought that the crop age probably dominates the seasonal effect upon crop development.

4. *On Percentage of Tops (Table 2 in Appendix):*

The effects from all four nitrogen treatments upon the percentage of tops in the total green weight were very similar. Thus from all of the N-fertilized plots, we harvested cane which had 30 per cent tops at 5½ months, 20 per cent tops at 11½ months, and not much more or less than 10 per cent tops at 17½ months and at the final harvest. These figures compare very well with those from the plant crop, except at 5½ months when the plant crop had 40 per cent of its green weight as tops.

5. *On Per Cent Moisture in Total Green Weight (Fig. 4) (Table 3 in Appendix):*

The higher nitrogen applications have again produced cane crops with a higher moisture content. For the first 7½ months the nitrogen-fertilized cane carried around 80 per cent moisture, thereafter it dropped to less than 75 per cent. The 60-pound nitrogen applications that were made in April effected an immediate increase in the moisture content of Treatments B and D over Treatments A and C respectively. The slight increase in moisture of the crops which did not get any additional nitrogen in April is probably due to the increased sucker growth which

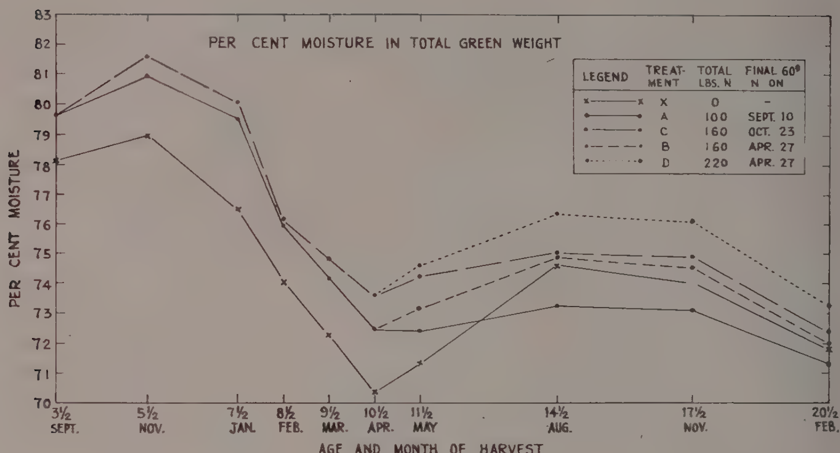

Fig. 4.

was becoming more obvious; this is indicated by the fact that the number of non-millable suckers was at its peak in May at 11½ months, and that the peak for suckers with millable cane was reached three months later.

6. *On Per Cent Fiber in Total Green Weight (Fig. 5) (Table 4 in Appendix):*

A study of the percentages of fiber in the total green weight harvested tends to

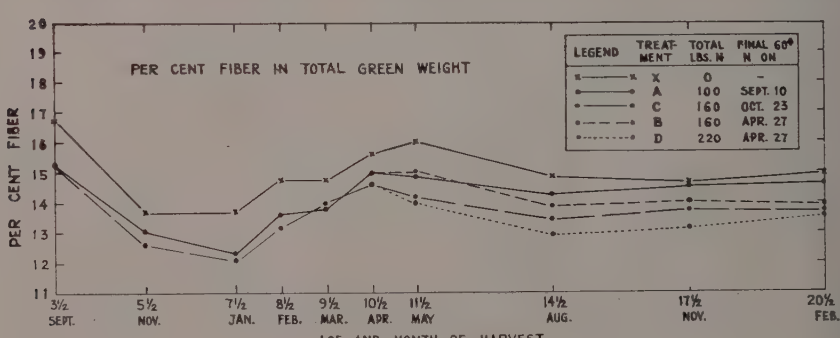

Fig. 5.

show an effect from the nitrogen applications that is almost the reverse of what we found for the moisture relations. The higher applications appear to have produced a crop with a lower percentage of fiber and as was the case with moisture, these effects have occurred quickly.

7. *On Total Dry Weight (Fig. 6) (Table 5 in Appendix):*

The relationships between the treatment effects on the total dry weights follow quite closely those already discussed under total green weight. There is this difference however—the decreased rate of production of total green weight between 7½ and 9½ months is not apparent in the dry weight; in fact the production of total dry matter was at pretty close to a constant rate throughout the entire growing

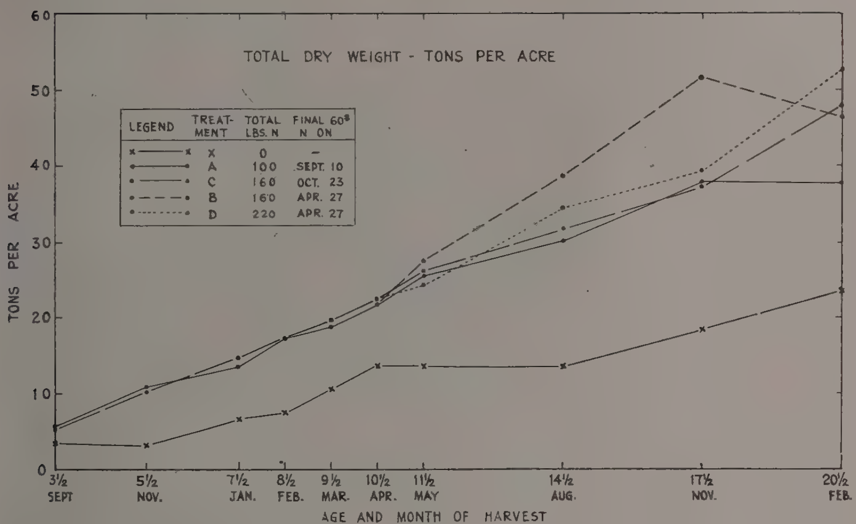

Fig. 6.

period, except for Treatment B which seemed to get an accelerated spurt from its April nitrogen application. Apparently then, the aforementioned slow up in green-weight production was largely an effect from its decreased moisture content that we recorded for this same period.

8. *On the Composition of the Total Dry Weight:*

(a) *Per cent reducing sugars (Fig. 7) (Table 6 in Appendix):* The effect from the different nitrogen treatments upon the percentage of reducing sugar is again a very definite and positive one; each increase in nitrogen fertilizer has caused an immediate and corresponding increase in the concentration of these sugars in the crop produced. In spite of the high experimental error associated with this measurement the treatment differences in the last four harvests are highly significant.

As was the case in the plant crop, we again note that the generally high concentrations of reducing sugar found in the first few harvests drop quite sharply and in all treatments are at a low level when the crop is 9½ to 11½ months old. Thereafter their increase is probably associated with the rapid development of the sucker growth which occurred between 11½ and 14½ months. The more gradual reduction which comes with the increased crop age eventually brings all but the high-nitrogen treatment (D) to less than two per cent at the final harvest.

(b) *Per cent sucrose (Fig. 8) (Table 7 in Appendix):* The effect of nitrogen on the percentage of sucrose, although not as clear as the effect on reducing sugars, is nevertheless quite the opposite, for we find a lower per cent sucrose in the higher nitrogen-fertilized cane. These undesirable effects from increased nitrogen are quite significant especially in those later harvests that were made before any attempts were made to "dry off" the field.

The increase in sucrose concentration from all treatments was very rapid during the first fall and winter months before the cane was 7½ months old. After this there was but little further change during the spring and summer, but another in-

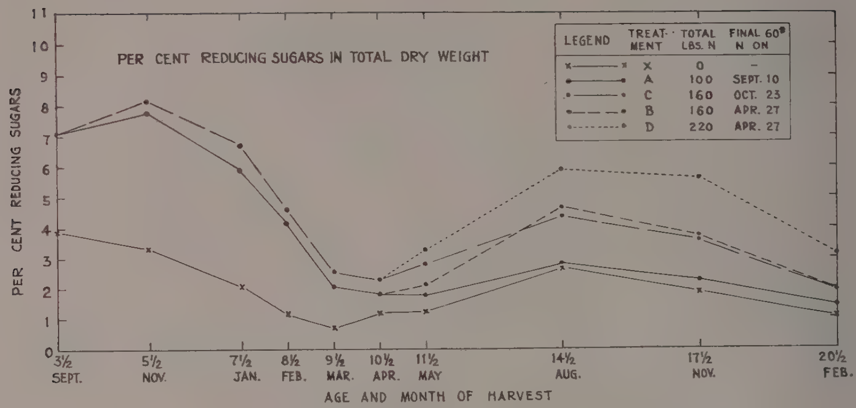

Fig. 7.

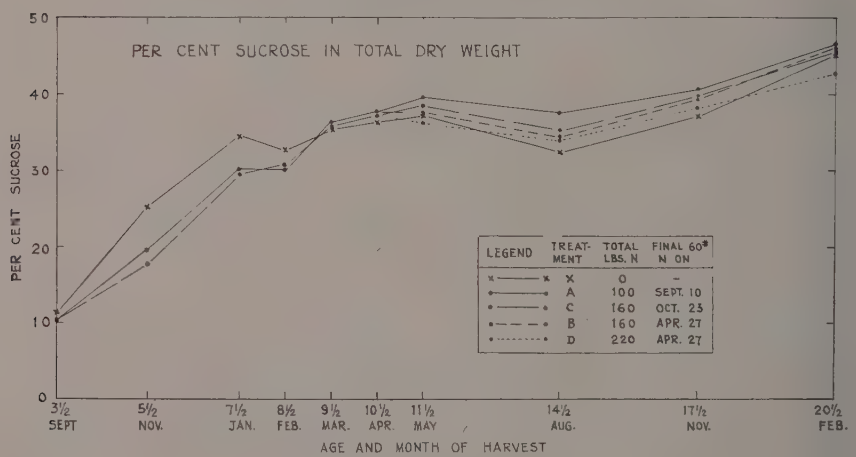

Fig. 8.

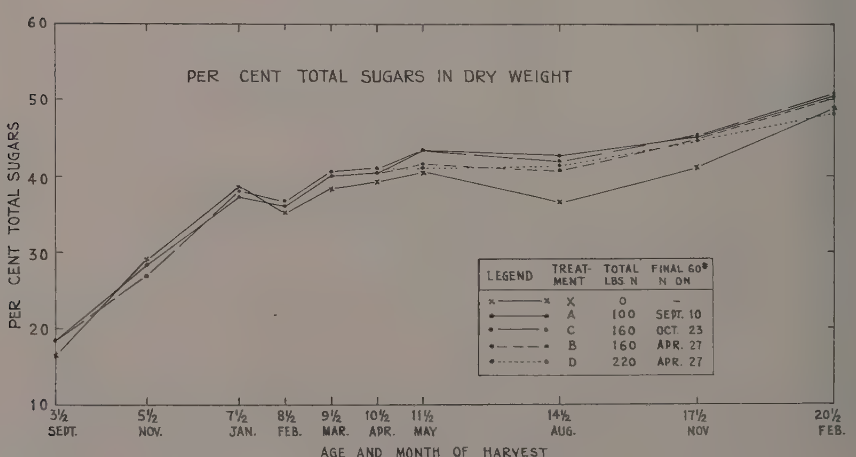

Fig. 9.

crease which started in the second fall continued to the final harvest in February. These results suggest seasonal effects on this component of the sugar cane crop.

(c) *Per cent total sugars (Fig. 9) (Table 8 in Appendix):* The concentration of the total sugars in this crop was apparently not differentially influenced by the nitrogen fertilization. This fact tends to confirm an opinion we advanced when similar results were found from the plant crop—i.e., some factor other than nitrogen has a greater influence on the percentage of total sugars. We are inclined to think that this may be largely an age factor since the rapid increase, which occurred in the concentration of total sugars between September and January for this crop, compares with a similar increase obtained between November and March for the plant crop, from cane which in both instances was between 3½ and 7½ months old. Another increase came between the ages of 14½ and 20½ months for both crops; in this ratoon crop these ages occurred between August and February whereas in the plant crop they came between October and April.

(d) *Per cent nitrogen (Fig. 10) (Table 9 in Appendix):* All nitrogen applications had an immediate effect upon the percentage of nitrogen in the total dry weight. Each additional amount of nitrogen applied produced a significant increase in the nitrogen concentration of the plant. In the fertilized canes this nitrogen concentration was highest at the age of 5½ months in November. It declined at a very constant rate during the following six months and thereafter remained at its relatively low level for the remainder of the crop.

At the age of 7½ months (in January) Treatment A which had received nitrogen at the rate of only 100 pounds per acre had .46 per cent N in its total dry weight, whereas the nitrogen in Treatment C which had received 160 pounds N per acre was at .59 per cent N. At 10½ months (in April) Treatment A had dropped to .29 per cent and Treatment C to .37 per cent N.

In our search for guidance in nitrogen fertilization, these latter figures need careful study for their relations with the actual yields secured from the field plots at their harvest at 22 months, and also for their comparison with similar relations established from the plant crop. To facilitate such a study we have prepared Table II. In the plant crop, .34 per cent N in the total dry weight at 10½ months was below the critical limit because an additional 60-pound application of nitrogen resulted in a significant increase in sugar; on the other hand a level at .43 per cent N for this same age was apparently adequate for the additional 60 pounds of nitrogen at 11 months did not give further increases in yields. In this ratoon crop although the gains measured were not statistically significant, it may be tentatively assumed that both .29 per cent N and .37 per cent N which were found in the dry weight at 10½ months indicate an inadequate concentration to carry the crop for another 10½ months because the nitrogen fertilizer added at 11 months appears to have given increased sugar yields in both cases. This makes it look as though .37 per cent N in the dry weight is below the critical level for 10½ months cane.

The fact that the last 60-pound application of nitrogen was equally effective on the final sugar yields from cane which had received both 160 and 100 pounds leads one to assume that the similarity in the final sugar yields from Treatments B and D ratoons indicates that their differences in the early nitrogen applications, *i.e.,* 100 vs. 160 pounds had not had much effect upon their yields within the first 10½ months. This fact is nicely shown in Fig. 14.

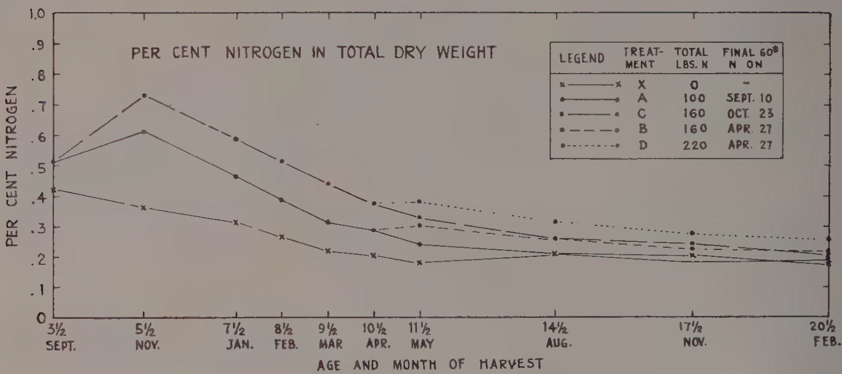
PER CENT NITROGEN IN TOTAL DRY WEIGHT
PER CENT NITROGEN
LEGEND TREATMENT TOTAL LBS. N FINAL 60# N ON
X 0 -
A 100 SEPT. 10
C 160 OCT. 23
B 160 APR. 27
D 220 APR. 27
3½ SEPT.
5½ NOV.
7½ JAN.
8½ FEB.
9½ MAR
10½ APR.
11½ MAY
14½ AUG.
17½ NOV.
20½ FEB.
AGE AND MONTH OF HARVEST

Fig. 10.

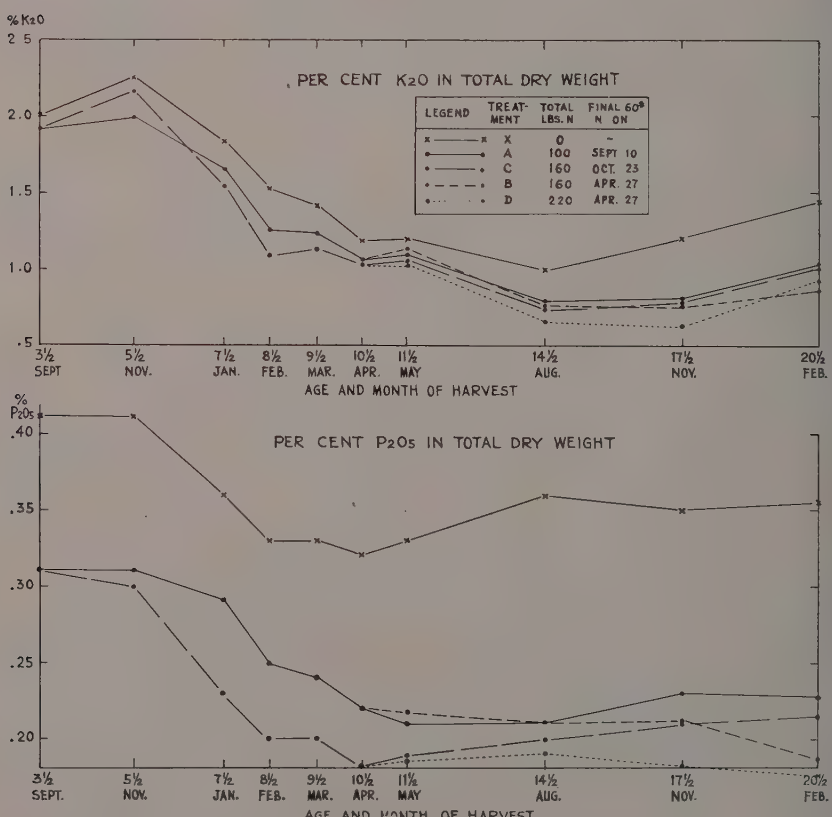
% K2O
PER CENT K2O IN TOTAL DRY WEIGHT
LEGEND TREATMENT TOTAL LBS. N FINAL 60# N ON
X 0 -
A 100 SEPT 10
C 160 OCT. 23
B 160 APR. 27
D 220 APR. 27
3½ SEPT
5½ NOV.
7½ JAN.
8½ FEB.
9½ MAR.
10½ APR.
11½ MAY
14½ AUG.
17½ NOV.
20½ FEB.
AGE AND MONTH OF HARVEST
% P2O5
PER CENT P2O5 IN TOTAL DRY WEIGHT
AGE AND MONTH OF HARVEST

Fig. 11.

TABLE II

RELATION BETWEEN PER CENT N IN DRY WEIGHT AT 10½ MONTHS AND THE FINAL FIELD YIELDS OF CANE AND SUGAR AT 22 MONTHS

Crop	No. of plots	Plot identity	At 10½ months Lbs. N applied	% N in dry wt.	Treatment	Additional N at 11 mos. (lbs.)	Field yields at 22 mos. T.C.A.	Y%C	T.S.A.
Plant	16	A+B	100	.34	A	0	111	13.9	14.7
					B	60	120	13.2	15.7
	16	C+D	160	.43	C	0	120	13.1	15.6
					D	60	123	12.7	15.5
Ratoon	16	A+B	100	.29	A	0	115	11.1	12.7
					B	60	127	10.5	13.2
	16	C+D	160	.37	C	0	126	10.1	12.6
					D	60	137	9.7	13.2

(e) *Per cent phosphoric acid and potash (Fig. 11) (Tables 10 and 11 in Appendix):* The increased applications of nitrogen have been responsible for a lowered concentration of both phosphoric acid and potash in the total dry weights harvested. Like nitrogen, the percentages of P_2O_5 and K_2O were at their high point at 5½ months; thereafter they too declined and showed but little change after 11½ months.

The percentages of P_2O_5 were considerably higher in all harvests of this ratoon than from corresponding harvests of the plant crop, and this condition existed in spite of the fact that no phosphate fertilizer was applied for the ratoon crop. The K_2O percentages found in this crop were in most cases slightly lower than those from the plant crop, although both crops had received a total of 100 pounds K_2O per acre in their fertilizer.

(g) *Total nutrition and nutrition ratios:* In Table III we have again set down the percentages of N, P_2O_5, and K_2O as found in the total dry weight from each harvest. The effects from the different nitrogen applications are quite apparent. Each increment of nitrogen supplied has increased the per cent nitrogen but decreased the per cent of both phosphate and potash. This same trend, though not as distinct, was noted in the plant crop. Knowledge of the fact that differences in the available nitrogen supply can affect the concentrations of P_2O_5 and K_2O in the cane crop is going to place a considerable handicap on attempts to interpret these mineral plant food analyses.

Our attempts to interpret the sum total of the percentages of N, P_2O_5, and K_2O as an index of total nutrition, and of their milli-equivalent ratios as indices of the quality of nutrition have not been especially successful. In almost every instance the total nutrition in the nitrogen-deficient cane (Treatment X) was actually higher than in the nitrogen-fertilized cane. Furthermore, differences in the total nutrition of the four nitrogen treatments were never large enough to be reliably identified with the amounts of nitrogen that had been made available for the crop. From the plant crop in which Treatment B gave the maximum sugar yields at the final harvest, we recorded the total nutrition just before harvest as 1.338 per cent and the quality of nutrition as 38–15–47. From the present ratoon crop, we find that the final sugar yield from Treatment B is associated with a total nutrition of 1.327 and a

quality of nutrition of 35–18–47. The figures from these two crops appear to be quite similar and yet the sugar yield from the plant crop was 2½ tons greater.

TABLE III

NUTRIENT COMPOSITION OF TOTAL DRY WEIGHTS

			Percentages in total dry weight						Pounds per acre in total dry weight	
Treatment	Age (mos.)	Lbs. N to date	N	P_2O_5	K_2O	Sum ($N+P_2O_5+K_2O$)	Ratio* $N–P_2O_5–K_2O$	$P_2O_5+K_2O$ ÷N	Total lbs. N, P_2O_5, K_2O	Proport. (%) N, P_2O_5, K_2O
X	3½	0	.421	.407	2.043	2.871	33–19–48	2.02	200	15–14–71
A	"	100	.512	.314	1.913	2.739	40–15–45	1.48	310	19–11–70
X	5½	0	.356	.410	2.270	3.036	28–19–53	2.58	187	12–13–75
A	"	100	.617	.306	1.991	2.914	44–13–43	1.26	624	21–11–68
C	"	160	.731	.298	2.168	3.197	47–11–42	1.13	663	23–9–68
X	7½	0	.316	.363	1.850	2.529	29–20–51	2.43	320	13–14–73
A	"	100	.459	.286	1.657	2.402	41–15–44	1.45	662	19–12–69
C	"	160	.583	.231	1.546	2.360	49–12–39	1.03	670	25–10–65
X	8½	0	.265	.333	1.527	2.125	29–21–50	2.46	312	12–16–72
A	"	100	.387	.251	1.264	1.902	43–16–41	1.36	645	20–13–67
C	"	160	.516	.198	1.088	1.802	54–12–34	.86	612	29–11–60
X	9½	0	.222	.329	1.416	1.967	27–23–50	2.78	432	11–17–72
A	"	100	.317	.243	1.239	1.799	38–17–45	1.62	675	18–13–69
C	"	160	.443	.196	1.139	1.778	49–13–38	1.03	690	25–11–64
X	10½	0	.203	.318	1.190	1.711	27–25–48	2.68	479	12–18–70
A	"	100	.286	.221	1.076	1.583	39–18–43	1.58	702	18–14–68
C	"	160	.374	.179	1.037	1.590	47–14–39	1.11	702	24–11–65
X	11½	0	.184	.327	1.207	1.718	25–26–49	3.01	469	11–19–70
A	"	100	.236	.210	1.105	1.551	34–18–48	1.92	809	15–14–71
B	"	160	.300	.217	1.133	1.650	39–17–44	1.56	903	18–13–69
C	"	160	.328	.186	1.065	1.579	43–15–42	1.30	825	21–12–67
D	"	220	.380	.185	1.051	1.616	47–14–39	1.11	778	24–11–65
X	14½	0	.207	.359	1.024	1.590	29–29–42	2.50	426	13–23–64
A	"	100	.205	.209	.788	1.202	36–22–42	1.75	716	17–17–66
B	"	160	.256	.207	.758	1.221	42–20–38	1.36	937	21–17–62
C	"	160	.255	.202	.757	1.214	42–20–38	1.35	776	21–17–62
D	"	220	.314	.189	.684	1.187	50–18–32	1.01	792	26–16–58
X	17½	0	.205	.351	1.212	1.768	26–27–47	2.78	647	12–20–68
A	"	100	.183	.229	.802	1.214	33–24–43	2.05	915	15–19–66
B	"	160	.241	.213	.777	1.231	40–21–39	1.48	1248	20–17–63
C	"	160	.229	.206	.785	1.220	39–21–40	1.56	922	19–17–64
D	"	220	.273	.183	.647	1.103	47–19–34	1.10	873	25–16–59
X	20½	0	.181	.356	1.450	1.987	22–26–52	3.56	935	9–18–73
A	"	100	.187	.227	1.021	1.435	30–21–49	2.35	1098	13–16–71
B	"	160	.208	.186	.933	1.327	35–18–47	1.87	1222	16–14–70
C	"	160	.209	.215	1.006	1.430	33–20–47	2.03	1350	15–15–70
D	"	220	.258	.175	.873	1.306	38–23–39	1.60	1349	20–14–66

*Based on chemical equivalents.

9. *On the Composition of Leaves and Crusher Juices:*

(a) *Per cent nitrogen in the leaf-punch samples (Fig. 12) (Table 12 in Appendix):* Once again we find an excellent reflection of the nitrogen applications in the per cent nitrogen found in the leaf-punch samples. Statistically significant effects were measured at each preharvest, even though the actual percentage differences were quite small. The concentration in the leaf blades was somewhat lower during the early growth stages than that found in the plant crop.

The very low experimental error again associated with this measurement con-

firms our confidence in its reliability, and we have found its correlation with per cent N in the total dry weight and also with per cent N in the crusher juice to be highly significant. There still remains however its satisfactory interpretation before its utilization as a guide for nitrogen fertilization can be considered reliable.

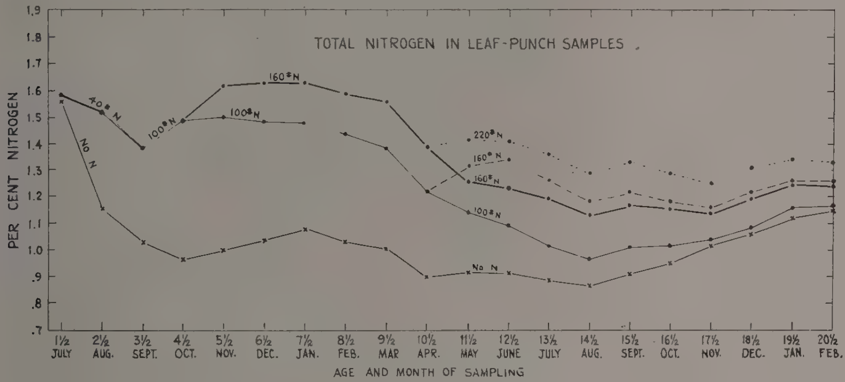

Fig. 12.

We have studied the data which show the relationship of the per cent N in the leaf-punch samples at 10½ months to the actual sugar yields when the field was finally harvested. Our objective still is to find a critical level for per cent N, especially just prior to that time when a deficiency, if identified, can be corrected by an additional application of fertilizer. In the plant crop, a concentration of 1.36 per cent nitrogen in the leaf-punch samples at 10½ months was indicated as too low, and a concentration of 1.46 per cent as fully adequate. In this ratoon it might be argued that although not proved significant, nevertheless because the final sugar yields from Treatments D and B were equal, and both were better than those from Treatments C and A respectively, both 1.38 per cent and 1.22 per cent N in the leaf-punch samples at 10½ months indicated a deficiency which an extra 60 pounds of N corrected. If this possibility is tentatively accepted, *i.e.*, that the 60-pound nitrogen applications in April did eventually result in similar and increased sugar yields, then we shall have to assume that Treatment C had an unnecessarily high N level prior to 10½ months and that that was an effect it received from the earlier 60-pound N increase over Treatment A in October. This may mean that perhaps it is not necessary to maintain a per cent N level in the leaf blades above 1.5 per cent at anytime, as there was certainly no visible indication during the early growth period of this crop that Treatment A was not making a satisfactory growth, or evidence that the production of total dry weight between Treatments A and C was different for at least 17½ months. Unfortunately the data do not furnish us with positive proof of an N percentage figure which may be construed as an adequate level in the leaf blades at 10½ months, unless we insist that since the treatment effects were not proved significant on the final yields, there was no real gain in sugar over that from Treatment A; in such case we would have to consider 1.22 per cent N in the leaf blades at 10½ months as adequately high; and this would be an amount somewhat less than we found to be inadequate in our plant crop! Clearly then we have not yet established the critical per cent N levels for leaf-punch samples.

(b) *Per cent nitrogen in the crusher juices (Fig. 13) (Table 13 in Appendix):* In this measurement too, we find a significant immediate effect from the different N applications at each preharvest, even though the coefficients of variation for this measurement were over 20 per cent. The setting up of a criterion of nitrogen deficiency or sufficiency for this analysis from this ratoon crop depends again upon whether one wishes to assume that there were or were not responses to the nitrogen applications above 100 pounds (Treatment A) in the final field yields. Statistically, such gains were not proved, but since this fact itself does not mean that such differences as were found might not have been proved gains if there had been still more replicates, we are perhaps not justified in dismissing either assumption; this makes

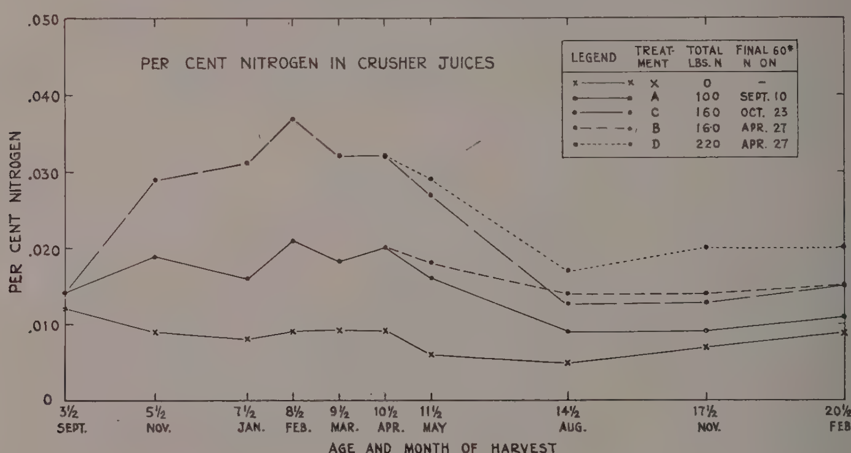

Fig. 13.

the interpretation even more difficult! For instance at the critically indicated age of 10½ months we find .020 per cent N in the crusher juice of cane which had been supplied with 100 pounds of N (Treatment A) and if one assumes that B eventually outyielded A, then this .020 per cent N level was too low, for B received an extra 60 pounds of N immediately thereafter. With similar reasoning one would then be forced to conclude that the .033 per cent N in the juice of cane from Treatment C which had received 160 pounds of N was also inadequate, since D which subsequently received another 60 pounds of N eventually produced more sugar than C. Thus these results would be in disagreement with those from the plant crop wherein .030 per cent N at 10½ months was shown to be fully adequate to produce the maximum sugar yields at the final harvest.

On the other hand if we accept the assumption that there was no gain for N applications greater than 100 pounds per acre (Treatment A) then we must conclude that .020 per cent N in the juice of cane at 10½ months was indicative of an adequate nitrogen status. This conclusion would be difficult to reconcile with the results from the plant crop which showed that a figure of .018 per cent was too low, *i.e.,* that additional nitrogen to cane with this low concentration did increase the final sugar yield!

10. *On the Yields per Acre:*

All interpretations which are based on yields per acre for the preharvest samples must be accepted as tentative because of the high experimental errors involved. Although the analysis of variance has been used to identify and separate the positional and treatment effects from the effects of error, the residual variations between the replicates are still large, and consequently very few treatment effects have been proved significant.

All figures given in the yield tables (except for Treatment X) are averages of 32 replicates at the first preharvest, of 16 replicates in the second to sixth preharvests, and of 8 thereafter. Averages from three X plots are listed but they were not used in the analysis of variance; thus the figure for the minimum difference required (M.d.r.) has no application to the yields from these X plots.

(a) *Reducing sugars, sucrose, and total sugars (Tables 14, 15, 16 in the Appendix):* In Table IV the data from the last four harvests are brought together for a study of the influence of nitrogen on the yields of reducing sugars, sucrose and total sugars. It will be seen that the higher nitrogen applications have given higher yields of reducing sugars, and the differences between Treatments A and D are highly significant at the last three harvests. Differences between C and B which both received 160 pounds of N, but with this total completed in October and the following April respectively, were not significant.

The effect of the nitrogen differentials on the yields of sucrose and of total sugars was quite similar. At 11½ months the high-nitrogen plots ("D") were the low producers, with very little difference between the other treatments. At 14½ months the "B" plots which had received their last 60 pounds of a 160-pound total application of N only four months previously, were ahead of the other treatments. At 17½ months, these same "B" plots were still in the lead in their sucrose and total sugar yields, with still very little difference between the other treatments. However, at the final preharvest at 20½ months, (1) the "A" plots (100 pounds N) had fallen down in their yields, (2) the "B" plots (160 pounds N, late) had not continued their previous rate of increase and were now a little behind the "C" plots (160 pounds N, early), and (3) the "D" plots had taken the lead.

TABLE IV

SUGARS IN TOTAL DRY WEIGHT—TONS PER ACRE

Treatment	Total lbs. N applied by April	Last 60 lbs. N applied	May harvest at 11½ mos. Tons per acre: Red. sugar	Sucrose	Total sugars	Aug. harvest at 14½ mos. Tons per acre: Red. sugar	Sucrose	Total sugars
A......	100	Sept.	.43	10.35	11.32	.83	11.37	12.80
B......	160	Apr.	.57	10.60	11.73	1.71	13.30	15.71
C......	160	Oct.	.74	10.02	11.29	1.37	11.44	13.40
D......	220	Apr.	.78	8.75	9.99	1.99	11.75	14.36

	Nov. harvest at 17½ mos. Tons per acre: Red. sugar	Sucrose	Total sugars	Feb. harvest at 20½ mos. Tons per acre: Red. sugar	Sucrose	Total sugars
A........................	.87	15.33	17.01	.49	17.38	18.79
B........................	1.92	20.26	22.77	.90	21.31	23.33
C........................	1.36	14.98	16.90	.86	22.03	24.04
D........................	2.20	14.96	17.63	1.65	22.25	25.07

(b) *Millable cane and recoverable sugar (Fig. 14) (Tables 17 and 18 in Appendix):* All yields that we have reported from the successive preharvests have been

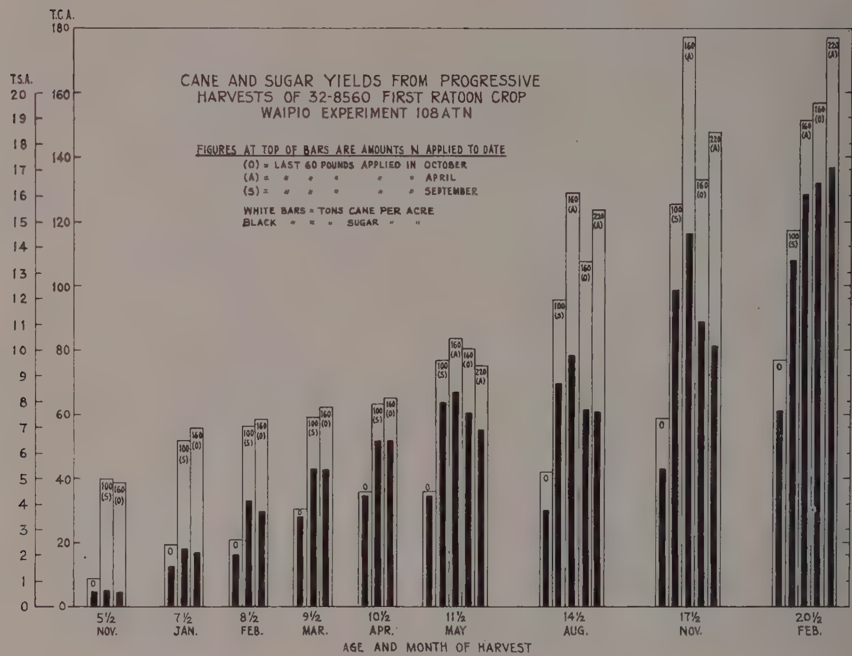

Fig. 14.

calculated on their actual net area basis of 25 square feet per plot; thus they will be found somewhat higher than respective field yields which would be calculated on gross acreage.

Our chief interest in these commercial yields rests in those from the last four harvests. At 11½ months the optimum sugar yield came from Treatment A which had received only 100 pounds N. At 14½ months and also at 17½ months there appears to be more sugar from Treatment B (160 pounds N—late) than from Treatment A (100 pounds N); but the increased amounts of cane that would have to be harvested and milled to get the extra sugar would indicate that Treatment A may still be the most profitable. However, Treatment C (160 pounds N—early) has not benefited by the extra 60 pounds of nitrogen it had received over Treatment A in October.

It seems logical to feel that the 220-pound application for Treatment D was excessive for cane harvested at 14½ or 17½ months, for there is nothing to suggest its superior effect on yield over the other plots that received nitrogen, but at the next harvest at 20½ months, the recoverable sugar from Treatment D had made a remarkable increase. Differences between treatments at 20½ months would seem to indicate that Treatment A (100 pounds) had now fallen behind the other treatments in sugar yields and that the 160 and 220 pounds N treatments were then about equal.

Table V has been prepared to show the increases and decreases made during successive growth periods. The variation between the treatments during the different growth stages needs careful study and rationalization. Average monthly gains in yields of cane were highest during Periods 4 and 5 while the crop was 11½ to 17½ months old. For sugar, the best monthly gains were made between 17½ and

20½ months and between 8½ and 11½ months. In the highly vegetative growth period between 11½ and 14½ months the increase in sugar was quite small.

Treatment B showed a remarkable spurt in cane yield after it was fertilized in April and made large increases during both Periods 4 and 5, but during the sixth growth period while it was being dried off, this cane appears to have suffered an enormous loss in yield. On the other hand Treatment C which had received its full 160-pound application of nitrogen six months earlier than Treatment B, made very consistent gains in millable cane yields throughout its last 12 months of growth and not only did not suffer from drying off but actually piled up a considerable increase in sugar during Period 6.

The large increase in T.C.A. made by Treatment D following the April fertilization was similar to that of Treatment B, but it did not continue through Period 5, nor was there any loss during drying off. In fact the cane and especially the sugar yield from Treatment D showed the greatest increase during this last Period 6.

TABLE V

AVERAGE INCREASES OR DECREASES IN YIELDS OF T.C.A. AND T.S.A.

Growth period	No. of months	Months	Age of crop (months)	T.C.A. (net area) X	A	B	C	D	Avg. per month for all 5 treatments
1	5½	May–Nov.	0–5½	+ 9.6	+37.1	+42.9	+38.0	+39.8	+6.7
2	3	Nov.–Feb.	5½–8½	+11.8	+16.0	+18.8	+19.4	+20.0	+5.7
3	3	Feb.–May	8½–11½	+15.7	+24.5	+21.8	+23.5	+15.8	+6.8
4	3	May–Aug.	11½–14½	+ 5.3	+18.2	+45.6	+26.7	+47.8	+9.6
5	3	Aug.–Nov.	14½–17½	+16.5	+29.4	+48.2	+25.4	+23.5	+9.5
6	3	Nov.–Feb.	17½–20½	+14.5	— 7.7	—25.8	+24.2	+29.6	+2.3
Period				T.S.A. (net area) X	A	B	C	D	
1				+ .51	+ .55	+ .77	+ .56	+ .59	+ .12
2				+1.58	+3.20	+3.78	+3.03	+3.40	+1.00
3				+2.24	+4.23	+3.70	+4.01	+3.05	+1.15
4				— .66	+ .68	+1.46	+ .10	+ .56	+ .14
5				+1.66	+3.65	+4.83	+3.39	+2.54	+1.07
6				+2.37	+1.23	+1.60	+5.40	+6.91	+1.17

Note: The horizontal bar (——) in the columns of Table V indicates that a nitrogen fertilizer application was made during the previous growth period.

TABLE VI

TONS SUGAR PER ACRE PER MONTH

Treatment	Total lbs. N applied by April	Last 60 lbs. N applied	Tons sugar per acre per month: May at 11½ mos.	August at 14½ mos.	November at 17½ mos.	February at 20½ mos.
A	100	September	.69	.60	.70	.66
B	160	April	.72	.67	.83	.79
C	160	October	.66	.53	.63	.80
D	220	April	.61	.52	.58	.83

On the basis of sugar-per-acre-per-month we have the figures in Table VI. At 11½, 14½ and 17½ months, the highest rate has come from Treatment B (160 pounds N—late), with the low rate from Treatment D (220 pounds). At 20½ months, Treatment A (100 pounds) has fallen behind the more adequately fertilized cane from the other three treatments.

(c) *Relation between recoverable sugar and total sucrose (Table VII):* The effects of the different amounts of nitrogen on the proportion of recoverable sugar

that was secured from the total sucrose made by the ratoon crop are shown in Table VII.

TABLE VII

RATIO OF T.S.A. TO TOTAL TONS SUCROSE

	At 5½ mos.	7½	8½	9½	10½	11½	14½	17½	20½
X	.63	.74	.89	.90	.87	.84	.86	.79	.74
A	.30	.55	.80	.79	.80	.77	.76	.80	.80
B	...	...	...	...	...	.78	.73	.71	.76
C	.31	.50	.72	.76	.78	.76	.67	.74	.75
D	...	...	...	...	...	.80	.65	.68	.76

When only 100 pounds of N was applied (Treatment A) this ratio was maintained after 7½ months at fairly close to 80 per cent, with only slightly lower recoveries at 11½ and 14½ months. From Treatment C (160 pounds N—early) this same ratio was never above 78 per cent and at 14½ months was down as low as 67 per cent. Treatment B (160 pounds N—late) reached its lowest ratio of .71 at 17½ months. Treatment D (220 pounds N) hit the low point of only 65 per cent at 14½ months and was still low (.68) three months later, but at the final harvest, 75-76 per cent of the total sucrose made by Treatments B, C, and D was then recoverable sugar.

11. *On Cane Quality (Fig. 15) (Table 19 in Appendix):*

The effects from additional increments of nitrogen fertilizer on cane quality are quite definite and similar to what has often been found to be true, *i.e.,* (1) each increment results in fewer pounds of recoverable sugar per 100 pounds of cane

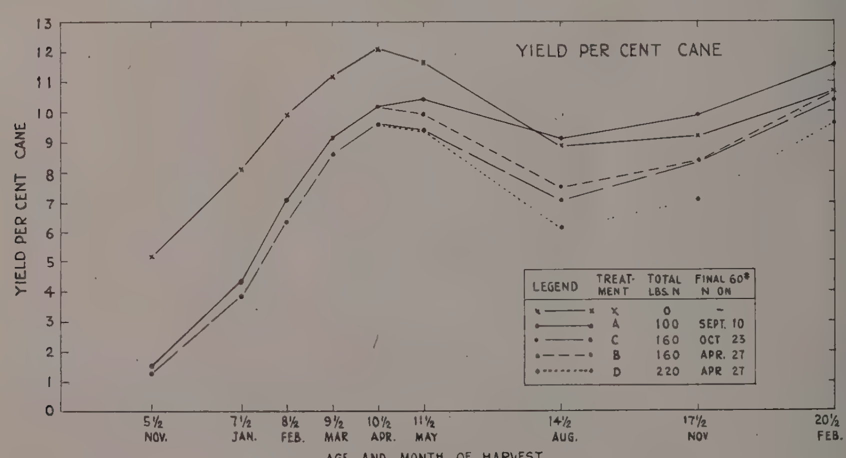

Fig. 15.

milled, and (2) there is little difference in the effect on quality from a difference in the time of application of the same total amount.

Regardless of nitrogen applied there were apparently two high peaks in yield per cent cane. One of these was reached at the early age of 10½-11½ months in April-May but immediately thereafter the cane quality dropped and was low at 14½ months in August. For the six months after this age, however, there was a steady

improvement. This verifies a similar condition found at 14½ months in the plant crop, which age was, however, reached in October, and so it appears that it is largely an age effect. If true, then we would do well to avoid harvesting 32-8560 cane at about 14½ months at any season of the year, in order to take full advantage of the probable improvement in quality and large increase in recoverable sugar that the subsequent six months should give us.

12. *On Tonnage of Cane Tops:*

As was to be expected, the increased nitrogen applications produced larger yields of cane tops. The averaged amounts were generally highest at 14½ months and in this respect they resembled the results from the fertilized plots of the plant crop. The lower amounts from the final harvest are partly the influence of a deliberate attempt to reduce the amount of tops by drying off the field; apparently this was not done quite as completely on this ratoon as on the plant crop.

AVERAGE TONS PER ACRE OF CANE TOPS (TREATMENTS A, B, C, AND D)

Crop	At 5½ mos.	At 8½ mos.	At 11½ mos.	At 14½ mos.	At 17½ mos.	At 20½ mos.
First ratoon	17.4	13.4	19.4	21.0	19.2	16.1
Plant	18.1	16.2	20.7	21.5	20.2	14.0

13. *On the Recovery of Nutrients in the Total Dry Weight*:*

(a) *Nitrogen (Fig. 16) (Table 20 in Appendix):* In this crop it was found that the cane in the no-N plots was not able to secure as much nitrogen as it had taken up

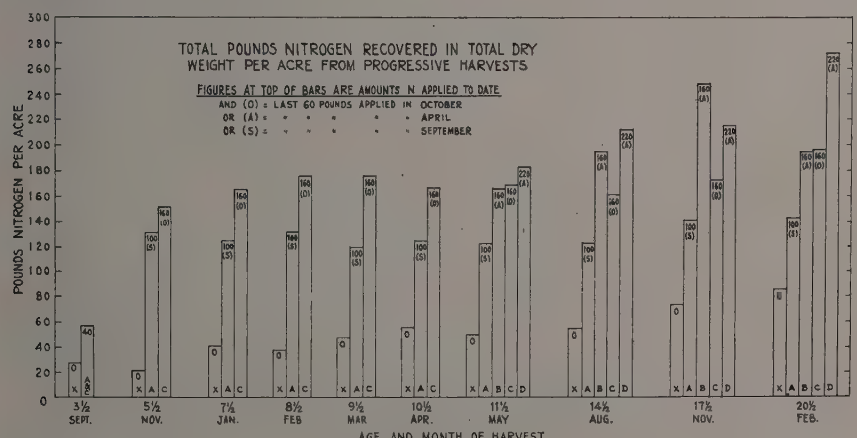

Fig. 16.

in the previous crop. We had suspected that this might be true from our observations of earlier leaf symptoms of nitrogen deficiency and the lower amounts of nitrogen in the monthly soil samples. The fact, however, that this non-fertilized cane did find an additional amount of nitrogen later in its growth period, is good evidence that the soil had made a late nitrogen contribution.

At 3½ months the fertilized cane had picked up only 58 pounds of nitrogen per acre, an amount quite comparable with that found in the plant crop (53 pounds) at

* Except trash and roots.

the same age from a similar nitrogen fertilizer application, even though this ratoon had made twice as much total dry weight by this age. Approximately half of this amount could have come from the soil's natural supplies and the other half from the 40-pound N application which had been made at the age of five weeks.

The fastest uptake of the applied nitrogen by this ratoon occurred between 3½ and 5½ months, and was especially noted following the 60-pound nitrogen applications in September. After the fall (Sept.-Oct.) applications, further increases in nitrogen recovery were very moderate. The April fertilization for Treatment B which then gave it a 160-pound total application was reflected in an immediate increase in nitrogen recovery, but the extra 60-pound April application for Treatment D to bring its total N to 220 pounds was not as quickly found in its crop. On the whole the amounts of nitrogen that were found in the successive harvests were considerably lower than the corresponding recoveries from the plant crop.

(b) *Phosphate and Potash (Fig. 17) (Tables 21 and 22 in Appendix):* The only significant effects from nitrogen applications upon the total recovery of phos-

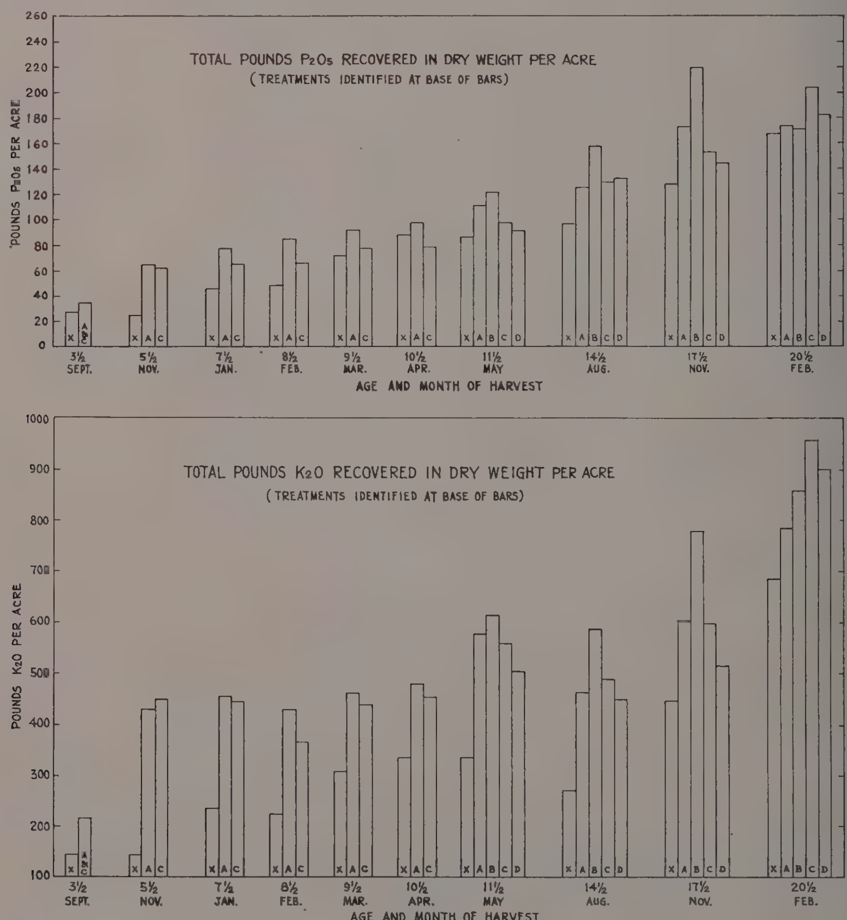

Fig. 17.

phate were found in the first-year harvests where slightly less phosphate was recovered from Treatment C than from Treatment A in spite of the fact that total dry weights from these two nitrogen treatments were very much alike. The actual amounts of phosphate recovered in the ratoon crops harvested were higher than from the plant crops, but were still not much over 100 pounds per acre until the crop entered its second year of growth. The ultimate amounts absorbed (about 180 to 200 pounds per acre) were more likely an effect of the crop's age than of its nitrogen differentials. The best treatments (B and D) took up about one pound of P205 for each ton of millable cane they produced.

The differences in total potash found in the dry weights were never proved to be a significant effect of the nitrogen treatments. The total amount in the crop at 3½ months had doubled itself at 5½ months, thus following a corresponding increase in the total dry weight. However, during the subsequent five months, there was little further increase in the amount of potash recovered although the dry weight was again doubled during this period. The maximum amounts in the crop at the final harvest were again large (in the neighborhood of 800 to 900 pounds per acre) and this fact cannot help but impress us with a realization of the heavy draft that cane crops make upon potash which is available to them.

Approximately 5 to 5½ pounds of potash had been taken up by this 32-8560 crop at 20½ months to produce each ton of millable cane.

Nitrogen Correlations

Between per cent nitrogen in leaf-punch samples and per cent nitrogen in (a) total dry weight and (b) crusher juice:

Generally speaking, our guidance for nitrogen fertilization will be sought from those analyses which are made while the crop is between six and 12 months old. In the present study we have looked for this guidance in the percentage of nitrogen found (1) in leaf-punch samples taken from the young active green-leaf blades, (2) in the total dry weight of samples which truly represent the complete crop as harvested, and (3) in the crusher juice samples from all living stalks with millable cane.

We have previously shown that each of these three samples has quite definitely reflected the different nitrogen levels which the treatments created. But in Table I we noted that the leaf-punch samples had much the lowest coefficients of variation, so it can be assumed that the leaf blades sampled are extremely homogeneous and would be the most dependable as a source of samples for nitrogen analysis.

The relationship between the percentages of nitrogen found in the leaf-punch samples and the corresponding composition of both total dry weight and crusher juices is shown in Table VIII. The correlation coefficients (r) are positive and highly significant, much more so than were found for the same analyses made from the plant crop.

TABLE VIII

CORRELATION BETWEEN NITROGEN ANALYSES

Age (mos.)	Average 32 plots* % N: In leaf	In dry wt.	In juice	Correlation (r) between % N in: Leaf and dry wt.	Leaf and juice
7½	1.55	.521	.024	.82∓.06	.85∓.05
8½	1.51	.452	.029	.81∓.06	.71∓.09
9½	1.47	.380	.025	.81∓.06	.67∓.10
10½	1.30	.330	.026	.84∓.05	.64∓.10
11½	1.28	.311	.023	.77∓.07	.48∓.14

*The "no-N" plots are not included.

Weather Relationships

In Table IX we have summarized the basic weather data during six growth periods, each of three months duration except the first one. With this we have included the associated yield data from Treatment B which has again been assumed to be the most efficient sugar producer. From Table IX we have then prepared Table X to show the relative effectiveness of the weather measurements on the yields. The data are not easy for us to interpret but we record them in the hopes that someone may be able to rationalize them. They do, however, indicate again that sunlight energy (as well as hours of sunshine and day-degrees) has a very different effect on yields in the different crop-age periods. To cite just one example, we note that the tons commercial sugar per 1000 gram calories of sunlight energy received was only .026 for Period 4 between May and August when the crop was 11½ to 14½ months old, whereas for the subsequent three months it was four times this amount.

TABLE IX
BASIC YIELD AND WEATHER DATA

Growth period	Dates	Crop age (mos.)	Increase in yields—tons/acre. Average of 8 "B" plots: Green wt.	Dry wt.	Tot. sugars	T.C.A.	T.S.A.
1	5/25–11/16	0–5½	57.01	10.88	3.13	40.0	.66
2	11/17–2/15	5½–8½	13.92	6.30	3.09	17.4	3.49
3	2/16–5/17	8½–11½	33.02	10.79	5.51	26.1	4.10
4	5/18–8/16	11½–14½	49.42	10.61	3.98	45.6	1.46
5	8/17–11/15	14½–17½	48.78	12.94	7.06	48.2	4.83
6	11/16–2/14	17½–20½	—34.99	—5.02	.56	—25.8	1.60

WEATHER MEASUREMENTS

Growth period	Gram calories	Hours of sunshine	Day-degrees	Avg. temperature Min.	Avg. temperature Max.	Range in temperature	Avg. wind velocity m.p.h.
1	96,469	1,299	2850	67.6°	86.4°	18.8°	6.0
2	32,672	500*	1089	64.3	82.0	17.7	4.7
3	48,995	630*	1129	62.7	82.4	19.7	5.4
4	56,545	658*	1602	68.1	87.5	19.4	6.0
5	45,202	602*	1720	66.7	88.7	22.0	5.1
6	33,101	504*	1248	62.0	84.0	22.0	4.7
Total	312,984	4,193*	9638				

*Instrument out of order; estimated from blueprint recorder relationship with Friez instrument.

TABLE X
SUNLIGHT AND TEMPERATURE UTILIZATION (BY TREATMENT B)

Growth period	Tons tot. green wt. per acre: Per 1000 gms. cal.	Per 100 hrs. sun	Per 1000 day-deg.	Tons tot. dry wt. per acre: Per 1000 gms. cal.	Per 100 hrs. sun	Per 1000 day-deg.	Tons tot. sugars per acre: Per 1000 gms. cal.	Per 100 hrs. sun	Per 1000 day-deg.
1	.591	4.389	20.004	.113	.838	3.818	.032	.241	1.098
2	.426	2.784*	12.782	.193	1.260*	5.785	.095	.618*	2.837
3	.674	5.241*	29.247	.220	1.713*	9.557	.112	.874*	4.880
4	.874	7.511	30.849	.188	1.612*	6.623	.070	.605*	2.484
5	1.079	8.102*	28.360	.286	2.149*	7.523	.156	1.173*	4.105
6	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)	.017	.011*	.449

Growth period	Tons millable cane per acre: Per 1000 gms. cal.	Per 100 hrs. sun	Per 1000 day-deg.	Tons comml. sugars per acre: Per 1000 gms. cal.	Per 100 hrs. sun	Per 1000 day-deg.
1	.415	3.079	14.035	.007	.051	.232
2	.533	3.480*	15.978	.107	.698*	3.205
3	.533	4.142*	23.118	.084	.651*	3.632
4	.806	6.930*	28.464	.026	.222*	.911
5	1.066	8.007*	28.023	.107	.802*	2.808
6	(loss)	(loss)	(loss)	.048	.032*	1.282

*Based on corrected estimate of hours of sunshine measured with blueprint recorder.

Other Interesting Relationships

1. *Ratio of Per Cent Total Sugars to Per Cent N in Total Dry Weight:*

In the September harvest at 3½ months we found that the 32 plots, which had all received 40 pounds of nitrogen in July, had a total sugar concentration that was 36 times the percentage of nitrogen. At the November harvest at 5½ months and at the four subsequent harvests, the effect of a difference in the amount of nitrogen applied had definitely made its impression on this per cent sugar/per cent N ratio. At 10½ months in April, a ratio of 145 parts of total sugars to one part of nitrogen was found in cane which had received only 100 pounds of nitrogen; the corresponding ratio from cane which had already been supplied with 160 pounds of N was 111 to 1 at this same harvest. Whether or not this larger 145-to-1 ratio represents an undesirably high carbohydrate-nitrogen status at this age depends upon our interpretation of the final yields; if we assume that Treatment B outyielded Treatment A (although this was not proved significant), then this ratio was too wide and the extra 60-pound nitrogen application was called for. Then by similar reasoning we would have to consider that Treatment D was better than C, and from this assumption conclude that the lower 111-to-1 ratio was also too high and needed lowering by the application of more nitrogen. Such reasoning will then need reconciliation with the finding that in the previous crop a ratio of 124 to 1 was proved to be too wide but one of 95 to 1 was apparently quite satisfactory.

RATIO OF PER CENT TOTAL SUGARS TO PER CENT N IN TOTAL DRY WEIGHT

Treatment	No. of plots.	November 5½ mos.	January 7½ mos.	February 8½ mos.	March 9½ mos.	April 10½ mos.	(Previous crop in June at 10½ mos.)
A+B	16	46.0	82.1	93.1	126.7	144.8	(124.0)
C+D	16	35.2	65.3	71.0	91.3	111.4	(95.1)

2. *Ratio of Pounds of Nitrogen per Acre Recovered in Crop to Tons Millable Cane Harvested:*

The number of pounds of nitrogen taken up by a crop for each ton of millable cane obtained at the last three harvests is shown below and the figures are not greatly different from results found from the plant crop. (Roots and dry trash are not included in these data.) Apparently only about 1.5 pounds of N will be needed to produce a ton of millable 32-8560 cane if its usage gets full efficiency.

Treatment	Pounds N per ton cane 14½ mos.	17½ mos.	20½ mos.
X	1.3	1.3	1.2
A	1.3	1.1	1.2
B	1.5	1.5	1.3
C	1.5	1.3	1.2
D	1.7	1.4	1.5

3. *Ratio of Per Cent Reducing Sugars to Per Cent Sucrose:*

Small but increased ratios of reducing sugars to sucrose were found from each additional nitrogen application. This was especially notable at the August harvest at 14½ months.

RATIO OF PER CENT REDUCING SUGARS TO PER CENT SUCROSE

Treatment	Harvested in— Sept.	Nov.	Jan.	Feb.	Mar.	Apr.	May	Aug.	Nov.	Feb.
X	.33	.13	.06	.04	.02	.03	.03	.08	.05	.02
A	.65	.39	.20	.14	.06	.05	.04	.07	.06	.03
B	..	..	..	..	..	..	.05	.13	.09	.04
C	..	.45	.23	.15	.07	.06	.07	.12	.09	.04
D	..	..	..	..	..	..	.08	.17	.15	.07

4. *Ratio of Total Sugars to Total Dry Weight (Tons per acre):*

The different nitrogen treatments had little if any effect on the ratios of total sugars to total dry weight. The ratio for Treatments A and C throughout the crop, and for B and A and for D and C after the April fertilizations had been applied to B and to D are almost identical, even though each of these pairs of treatments contained a nitrogen differential of 60 pounds per acre. The ratios have a great deal of similarity to those from the plant crop, and again we find that the total sugars make up just about 50 per cent of the total dry weight at 20½ months regardless of differences in the nitrogen fertilization of the cane crop which has been grown.

RATIO OF TOTAL SUGARS TO TOTAL DRY WEIGHT

Treatment	Harvested in— Sept.	Nov.	Jan.	Feb.	Mar.	Apr.	May	Aug.	Nov.	Feb.
X	.17	.30	.38	.49	.38	.39	.41	.36	.41	.48
A	.19	.29	.38	.36	.40	.41	.44	.43	.45	.50
B	..	..	..	..	..	..	.42	.41	.44	.50
C	..	.27	.38	.37	.40	.42	.43	.42	.45	.50
D	..	..	..	..	..	..	.41	.42	.45	.48

5. *Ratio of Tons Reducing Sugars to Total Dry Weight:*

We do, however, find again that the nitrogen treatments have increased the ratio of the tonnage of reducing sugars to the total dry weight. This is apparent from the A vs. C, A vs. B, and C vs. D comparisons which have had a 60-pound N differential.

RATIO OF TONS REDUCING SUGARS TO TOTAL DRY WEIGHT

Treatment	Harvested in— Sept.	Nov.	Jan.	Feb.	Mar.	Apr.	May	Aug.	Nov.	Feb.
X	.037	.032	.021	.012	.007	.012	.012	.027	.019	.010
A	.073	.079	.058	.040	.021	.018	.017	.028	.023	.013
B	...	...	...	...	...	...	.020	.044	.037	.019
C	...	.078	.066	.044	.024	.022	.028	.043	.036	.018
D	...	...	...	...	...	...	.032	.058	.056	.032

6. *Ratio of Tons Sucrose to Tons Dry Weight:*

The effect of nitrogen differentials upon the ratio of sucrose to dry weight appears to be very slight, all differences being very small ones. As was found in the plant crop, again about 46 per cent of the total dry weight was sucrose.

RATIO OF TONS SUCROSE TO TOTAL DRY WEIGHT

Treatment	Harvested in— Sept.	Nov.	Jan.	Feb.	Mar.	Apr.	May	Aug.	Nov.	Feb.
X	.12	.26	.34	.32	.35	.36	.38	.32	.37	.45
A	.11	.20	.30	.30	.36	.38	.40	.38	.40	.46
B	..	..	..	..	..	..	.38	.35	.39	.46
C	..	.18	.30	.31	.36	.37	.39	.36	.40	.46
D	..	..	..	..	..	..	.36	.34	.38	.43

7. *Ratio of Commercial Sugar to Total Dry Weight:*

This ratio of commercial sugar to total dry weight which is tabulated hereafter for the last four harvests tends to show slightly lower amounts associated with the increased nitrogen applications. Of general interest is the fact that only approximately 35 per cent of the total dry weight at the final harvest was calculated as commercial sugar, whereas we have previously shown about 46 per cent to be sucrose and 50 per cent to be total sugars.

RATIO OF TONS COMMERCIAL SUGARS TO TOTAL DRY WEIGHT

Treatment	Harvested in— May	August	November	February
X	.32	.27	.29	.33
A	.31	.29	.32	.36
B	.29	.25	.28	.35
C	.29	.24	.30	.35
D	.29	.22	.26	.33

Discussion

Most of the measurements obtained from the first ratoon crop in this study have already been adequately discussed, and to those who have critically examined the tables and graphs it is quite apparent that we have not yet attained our main objective, *i.e.*, the establishment of a critical nitrogen index. Part of our difficulty is due to the fact that in this ratoon our field experiment did not establish a proved effect for the four different nitrogen applications, *i.e.*, such differences in sugar yields as were found between these treatments could have been due to chance alone. Thus even though our eight replications of treatments resulted in a creditably low experimental error, we did not actually prove any gains in sugar (T.S.A.) for any nitrogen applications greater than 100 pounds per acre, as the following analysis of variance and yield summary will substantiate.

WAIPIO EXPERIMENT 108 ATN—FIRST RATOON—HARVESTED AT 22 MONTHS

Source	Degrees of freedom	Analysis of variance. Mean squares— In T.C.A.	In Y%C	For T.S.A.
Blocks	7	399.08*	4.59**	5.76**
Treatments	3	610.43**	3.07*	.91(ns)
Error	21	113.93	.86	.70
Coef. of variation		8.5%	9.0%	6.5%

*Significant. **Highly significant. (ns) = not significant.

SUMMARY OF FIRST RATOON YIELDS (AVERAGES FOR 8 PLOTS)

Harvested March 16 - April 4, 1944, Age 22 Months

Plot identity	Pounds N applied— July	Sept.	Oct.	April	Total	Yields per acre (gross area)— Tons cane	Y%C	Tons sugar
A	40	60	0	0	100	115.2	11.12	12.65
B	40	60	0	60	160	127.4	10.48	13.22
C	40	60	60	0	160	125.7	10.10	12.60
D	40	60	60	60	220	136.6	9.66	13.19
Min. difference needed for significance						11.1	.96	(.87)ns

Since we did measure a significant gain in T.S.A. for 160 pounds of N (Treatment B) over 100 pounds from the previous or plant crop,* and as it seems most unlikely that the first ratoon would make its optimum yield when cut at the same age, on less than 160 pounds, it is not altogether unreasonable to assume, at least tentatively, that Treatment B was again the optimum, and in much of the discussion which has preceded this, we have accepted this possibility.

Some of the more specific effects from the different applications of nitrogen have been pointed out. Thus we have again found that (1) the soil has contributed some of its nitrogen to the crop; (2) the heavier nitrogen fertilizer applications have resulted in greater yields of green weight, dry weight, and millable cane; (3) higher percentages of moisture, of reducing sugars, and of nitrogen in dry weight, leaf blades and crusher juice have come from the higher amounts of nitrogen; but (4) lower percentages of fiber, of sucrose, of phosphate and potash, and a lower yield per cent cane (poorer quality) have been the result of the increased nitrogen.

If we accept for the time being the opinion that Treatment B possibly did respond to its extra 60 pounds of N applied in April, then we can consider the following nitrogen levels in Treatment A of our 32-8560 cane crop at 10½ months, as indications of a nitrogen deficiency: (a) .29 per cent N in total dry weight, (b) 1.22 per cent N in the leaf-punch samples, and (c) .020 per cent N in the crusher juice. In the plant crop these deficiency levels were respectively .33, 1.36, and .018. Although these two sets of figures show a fair degree of similarity, we must not forget that we haven't yet estimated a reliable "sufficiency N level," and this will be a much more important one in the control of our sugar yields.

The study continues. The second ratoon crop is underway and the early preharvests are already being made.

Acknowledgments

Again it would have been impossible to make this study without the help of many staff members and their assistants. Hence we gratefully acknowledge the cooperation and the assistance supplied by all members of the several research laboratories and departments who have had a part in the large volume of work involved in an investigation of this nature.

* For comparison, the yields from the plant crop harvest are given below:

PLANT CROP—YIELDS
Harvested May 5-17, 1942, Age 21½ Months

Plot identity	Pounds N applied: Sept.	Nov.	March	June	Total	Yields per acre (gross area): Tons cane	Y%C	Tons sugar
A	40	60	0	0	100	110.9	13.9	14.7
B	40	60	0	60	160	120.0	13.2	15.7
C	40	60	60	0	160	120.2	13.1	15.6
D	40	60	60	60	220	122.7	12.7	15.5
Min. difference needed for significance						ns	.67	.56

Appendix

CONTAINING SUMMARIES OF DATA AND STATISTICAL MEASUREMENTS THEREOF FROM WAIPIO EXPT. 108 ATN—FIRST RATOON CROPS

(Measurements from the 3 "X" Plots were not included in the statistical computations)

S.D. = Standard Deviation.
C.V. = Coefficient of Variation.
M.d.r. = Minimum difference required for significance between Treatments A, B, C, and D only.
ns = Treatment effect not significant.

TABLE 1

TOTAL GREEN WEIGHT—TONS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	15.97	14.62	26.94	27.88	39.31	47.33	47.48	53.10	70.93	83.09
A	28.44	57.01	66.69	70.93	73.52	79.71	94.85	112.71	141.84	130.49
B	.....	.....	.....	.....	.....	.....	103.95	153.37	202.15	167.16
C	.....	56.29	71.46	71.75	78.21	83.73	100.84	127.68	150.09	172.58
D	.....	.....	.....	.....	.....	.....	95.22	145.67	165.23	195.97
S.D.	10.1	13.6	11.5	16.3	17.1	16.1	38.3	29.9	54.7	51.9
C.V.	35.5	24.1	16.7	22.9	22.5	19.7	38.8	22.1	33.2	31.2
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 2

PER CENT TOPS IN TOTAL GREEN WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	54.41	34.97	26.77	23.39	21.93	22.07	22.21	20.22	17.50	11.93
A	50.56	30.62	22.12	19.18	19.68	19.27	18.21	15.05	11.54	10.06
B	.....	.....	.....	.....	.....	.....	19.88	15.97	12.43	9.50
C	.....	30.92	21.59	18.40	20.02	20.36	19.90	15.87	11.38	9.10
D	.....	.....	.....	.....	.....	.....	20.59	15.25	11.14	10.00
S.D.	6.08	3.98	2.56	2.97	1.48	2.60	2.10	1.68	1.72	1.43
C.V.	12.0	12.9	11.7	15.8	7.5	13.1	10.7	10.8	14.8	14.7
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 3

PER CENT MOISTURE IN TOTAL GREEN WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	78.17	78.96	76.53	74.00	72.35	70.47	71.42	74.60	74.08	71.88
A	79.61	80.89	79.52	75.88	74.25	72.47	72.48	73.29	73.16	71.40
B	.....	.....	.....	.....	.....	.....	73.16	74.94	74.57	72.07
C	.....	81.56	80.06	76.15	74.87	73.60	74.21	75.00	74.96	72.47
D	.....	.....	.....	.....	.....	.....	74.54	76.44	76.17	73.31
S.D.	1.04	.91	1.37	1.19	1.14	1.01	1.42	1.27	1.04	1.55
C.V.	1.3	1.1	1.7	1.6	1.5	1.4	1.9	1.7	1.4	2.1
M.d.r.	.....	.66	ns	ns	ns	.75	1.48	1.31	1.08	ns

TABLE 4

PER CENT FIBER IN TOTAL GREEN WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	16.73	13.70	13.73	14.73	14.71	15.67	16.03	14.85	14.69	14.95
A	15.23	13.07	12.29	13.57	13.87	14.99	14.90	14.27	14.50	14.52
B	.....	.....	.....	.....	.....	.....	14.97	13.80	14.08	13.88
C	.....	12.59	12.11	13.19	13.90	14.58	14.17	13.46	13.72	13.67
D	.....	.....	.....	.....	.....	.....	14.13	12.94	13.18	13.53
S.D.	1.05	.71	.56	.94	.91	.93	.94	.62	.76	.85
C.V.	6.9	5.5	4.6	7.0	6.6	6.3	6.5	4.6	5.5	6.1
M.d.r.	.....	ns	ns	ns	ns	ns	ns	.64	.79	ns

TABLE 5

TOTAL DRY WEIGHT—TONS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	3.50	3.11	6.32	7.23	10.84	13.98	13.60	13.47	18.22	23.53
A	5.73	10.88	13.68	17.18	18.97	21.92	25.93	30.06	37.93	37.72
B	.....	.....	.....	.....	.....	.....	27.97	38.58	51.52	46.50
C	.....	10.46	14.32	17.20	19.78	22.19	26.03	31.96	37.57	47.76
D	.....	.....	.....	.....	.....	.....	24.22	34.53	39.35	52.36
S.D.	1.90	2.76	2.49	4.30	4.86	4.39	9.94	7.58	13.85	14.90
C.V.	33.2	25.9	17.8	25.0	25.1	19.9	38.2	22.4	33.3	32.3
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 6

PER CENT REDUCING SUGARS IN TOTAL DRY WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	3.90	3.38	2.03	1.16	.73	1.17	1.23	2.69	1.80	1.02
A	7.03	7.75	5.89	4.08	2.08	1.79	1.70	2.76	2.25	1.47
B	.....	.....	.....	.....	.....	.....	2.06	4.56	3.69	1.93
C	.....	8.11	6.73	4.56	2.50	2.24	2.82	4.37	3.62	1.93
D	.....	.....	.....	.....	.....	.....	3.24	5.86	5.60	3.12
S.D.	1.19	1.32	.88	.77	.70	.51	.77	.80	.81	.82
C.V.	17.0	16.6	13.9	17.8	30.6	25.4	31.3	18.2	21.4	38.9
M.d.r.	.....	ns	.64	ns	ns	.37	.81	.83	.84	.85

TABLE 7

PER CENT SUCROSE IN TOTAL DRY WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	11.88	25.13	34.33	32.51	35.76	36.35	37.24	32.15	37.36	45.35
A	10.82	19.66	30.19	30.15	36.05	37.69	39.66	37.95	40.62	46.39
B	.....	.....	.....	.....	.....	.....	37.60	34.39	39.67	45.86
C	.....	17.92	29.71	30.43	35.99	37.37	38.60	35.67	39.81	46.16
D	.....	.....	.....	.....	.....	.....	36.31	34.01	38.17	42.78
S.D.	1.61	1.62	3.51	2.56	1.78	2.97	2.12	2.18	1.61	2.77
C.V.	14.9	8.6	11.7	8.6	4.9	7.9	5.6	6.1	4.1	6.1
M.d.r.	.....	1.18	ns	ns	ns	ns	2.20	2.27	1.66	ns

TABLE 8

PER CENT TOTAL SUGARS IN TOTAL DRY WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	16.40	29.01	38.17	35.38	38.37	39.42	40.43	36.53	41.14	48.75
A	18.41	28.38	37.68	36.04	40.04	41.47	43.44	42.71	45.01	50.30
B	.....	.....	.....	.....	.....	.....	41.65	40.76	44.87	50.20
C	.....	26.98	38.00	36.59	40.39	41.64	43.46	41.91	44.95	50.52
D	.....	.....	.....	.....	.....	.....	41.46	41.66	44.79	48.14
S.D.	.75	2.19	3.64	2.54	1.97	3.01	2.19	2.09	2.86	2.74
C.V.	4.1	7.9	9.6	7.0	4.9	7.2	5.2	5.0	6.4	5.5
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 9

PER CENT NITROGEN IN TOTAL DRY WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.421	.356	.316	.265	.222	.203	.184	.207	.205	.181
A	.512	.617	.459	.387	.317	.287	.237	.205	.183	.187
B	.....	.....	.....	.....	.....	.....	.301	.256	.241	.208
C	.....	.731	.583	.516	.443	.374	.329	.255	.229	.209
D	.....	.....	.....	.....	.....	.....	.380	.314	.273	.258
S.D.	.045	.088	.050	.051	.046	.029	.040	.032	.024	.034
C.V.	8.8	13.1	9.6	11.3	12.1	8.8	12.9	12.5	10.4	15.8
M.d.r.	.....	.064	.037	.037	.034	.021	.042	.033	.025	.035

TABLE 10

PER CENT P_2O_5 IN TOTAL DRY WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.41	.41	.36	.33	.329	.318	.327	.359	.351	.356
A	.31	.31	.29	.25	.243	.221	.210	.209	.229	.227
B	.....	.....	.....	.....	.....	.....	.217	.207	.213	.186
C	.....	.30	.23	.20	.196	.179	.186	.202	.206	.215
D	.....	.....	.....	.....	.....	.....	.185	.189	.183	.175
S.D.	.04	.028	.03	.03	.024	.017	.031	.021	.021	.027
C.V.	12.9	9.3	11.5	13.6	10.9	8.5	15.5	10.4	10.1	13.4
M.d.r.	.....	ns	.02	.02	.018	.012	ns	ns	.021	.028

TABLE 11

PER CENT K_2O IN TOTAL DRY WEIGHT

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	2.04	2.27	1.85	1.53	1.42	1.188	1.207	1.024	1.212	1.450
A	1.91	1.99	1.66	1.26	1.24	1.075	1.104	.788	.803	1.021
B	.....	.....	.....	.....	.....	.....	1.130	.759	.777	.933
C	.....	2.17	1.55	1.09	1.14	1.037	1.064	.757	.785	1.006
D	.....	.....	.....	.....	.....	.....	1.051	.684	.647	.873
S.D.	.26	.21	.25	.23	.18	.174	.170	.104	.074	.131
C.V.	13.6	10.1	15.6	19.5	15.1	16.5	15.6	13.9	9.8	13.7
M.d.r.	.....	.16	ns	.17	ns	ns	ns	ns	.077	.136

TABLE 12

PER CENT NITROGEN IN LEAF-PUNCH SAMPLES

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	1.03	1.00	1.08	1.04	1.01	.90	.92	.87	1.02	1.15
A	1.38	1.50	1.47	1.44	1.38	1.22	1.14	.97	1.04	1.16
B	....	....	....	....	....	....	1.31	1.18	1.16	1.26
C	....	1.62	1.63	1.59	1.56	1.38	1.26	1.13	1.14	1.24
D	....	....	....	....	....	....	1.43	1.28	1.25	1.33
S.D.	.055	.033	.017	.022	.02	.03	.03	.04	.06	.06
C.V.	4.0	2.1	1.1	1.5	1.4	2.3	2.3	3.5	5.2	4.8
M.d.r.	....	.03	.01	.02	.01	.02	.03	.04	.06	.06

TABLE 13

PER CENT NITROGEN IN CRUSHER JUICES

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.012	.009	.008	.008	.009	.009	.006	.005	.007	.009
A	.014	.019	.016	.021	.018	.020	.016	.009	.009	.011
B	....	....	....	....	....	....	.018	.014	.014	.015
C	....	.028	.031	.037	.033	.033	.027	.013	.013	.015
D	....	....	....	....	....	....	.029	.017	.020	.020
S.D.	.003	.007	.005	.006	.008	.009	.005	.003	.003	.003
C.V.	21.4	29.2	20.8	20.7	32.0	34.6	21.7	23.1	21.4	20.0
M.d.r.	....	.005	.004	.005	.006	.006	.006	.003	.003	.004

TABLE 14

REDUCING SUGARS—TONS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.13	.10	.13	.09	.08	.17	.16	.36	.34	.23
A	.42	.86	.79	.68	.40	.39	.43	.83	.87	.49
B	....	....	....	....	....	....	.57	1.71	1.92	.90
C	....	.82	.95	.76	.48	.49	.74	1.37	1.36	.86
D	....	....	....	....	....	....	.78	1.99	2.20	1.65
S.D.	.19	.23	.18	.16	.13	.15	.33	.42	.68	.46
C.V.	45.2	27.4	20.7	21.9	29.5	34.1	52.4	28.4	42.8	47.4
M.d.r.	....	ns	.13	ns	ns	ns	ns	.44	.71	.48

TABLE 15

SUCROSE—TONS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.42	.81	2.16	2.34	3.82	5.07	5.14	4.27	6.74	10.47
A	.64	2.17	4.14	5.21	6.83	8.21	10.35	11.37	15.33	17.38
B	....	....	....	....	....	....	10.60	13.30	20.26	21.31
C	....	1.88	4.26	5.26	7.14	8.31	10.02	11.44	14.98	22.03
D	....	....	....	....	....	....	8.75	11.75	14.96	22.25
S.D.	.28	.62	.92	1.49	1.74	1.61	3.91	2.71	5.45	6.64
C.V.	43.8	30.7	21.9	28.4	24.9	19.5	39.4	22.6	33.3	32.0
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 16

TOTAL SUGARS—TONS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.58	.92	2.40	3.55	4.10	5.50	5.58	4.86	7.44	11.24
A	1.10	3.13	5.15	6.22	7.59	9.04	11.32	12.80	17.01	18.79
B	....	....	....	....	....	....	11.73	15.71	22.77	23.33
C	....	2.80	5.44	6.31	7.99	9.26	11.29	13.40	16.90	24.04
D	....	....	....	....	....	....	9.99	14.36	17.63	25.07
S.D.	.49	.85	1.06	1.71	1.91	1.79	4.38	3.12	6.03	7.23
C.V.	44.5	28.6	20.0	27.3	24.5	19.6	39.5	22.2	32.5	31.7
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 17

MILLABLE CANE—TONS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	7.30	9.59	19.71	21.36	30.83	36.88	37.04	42.29	58.78	73.23
A	14.65	40.03	51.99	57.42	59.03	64.33	77.64	95.88	125.32	117.59
B	.....	.....	.....	.....	.....	.....	83.48	129.08	177.26	151.50
C	.....	38.90	55.93	58.61	62.42	66.47	80.85	107.55	132.96	157.13
D	.....	.....	.....	.....	.....	.....	75.65	123.49	146.99	176.56
S.D.	6.51	10.64	9.30	13.84	13.51	12.43	31.21	25.90	49.47	49.28
C.V.	44.6	26.9	17.2	23.9	22.3	19.0	39.3	22.7	34.0	32.7
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 18

COMMERCIAL SUGARS—TONS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.02	.51	1.59	2.09	3.47	4.40	4.33	3.67	5.33	7.70
A	.02	.66	2.28	4.15	5.40	6.51	7.98	8.66	12.31	13.54
B	.....	.....	.....	.....	.....	.....	8.25	9.71	14.54	16.14
C	.....	.58	2.15	3.79	5.42	6.49	7.60	7.70	11.09	16.49
D	.....	.....	.....	.....	.....	.....	7.04	7.60	10.14	17.05
S.D.	.05	.37	.65	1.45	1.42	1.50	3.00	1.94	4.09	5.43
C.V.	250.0	59.7	29.5	36.3	26.3	23.1	39.0	23.1	34.1	34.4
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

TABLE 19

YIELD PER CENT CANE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	.21	5.2	8.1	9.9	11.2	12.1	11.6	8.8	9.2	10.7
A	.20	1.5	4.3	7.1	9.1	10.2	10.4	9.1	9.8	11.5
B	.....	.....	.....	.....	.....	.....	9.9	7.5	8.3	10.7
C	.....	1.3	3.8	6.4	8.6	9.6	9.4	7.1	8.3	10.4
D	.....	.....	.....	.....	.....	.....	9.4	6.2	7.1	9.7
S.D.	.40	.66	.78	1.14	.76	1.30	.85	1.07	1.05	1.08
C.V.	20.0	47.1	19.5	17.0	8.5	13.1	8.7	14.3	12.5	10.2
M.d.r.	.....	ns	ns	ns	ns	ns	ns	1.1	1.1	1.1

TABLE 20

NITROGEN IN TOTAL DRY WEIGHT—POUNDS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	29.2	21.9	40.2	39.0	48.5	56.9	50.0	55.6	74.4	85.8
A	57.8	132.0	126.2	131.8	119.8	125.6	122.8	122.8	140.1	141.0
B	.....	.....	.....	.....	.....	.....	165.8	195.7	248.5	193.9
C	.....	152.5	166.2	175.8	174.6	166.7	168.1	160.4	172.6	194.5
D	.....	.....	.....	.....	.....	.....	183.0	211.5	214.0	271.6
S.D.	16.88	37.59	31.54	34.67	38.18	32.51	59.55	39.01	64.45	75.95
C.V.	29.2	26.4	21.6	22.5	25.9	22.2	37.2	22.6	33.3	37.9
M.d.r.	.....	ns	23.1	25.4	27.9	23.8	ns	40.6	67.0	79.0

TABLE 21

P_2O_5 IN TOTAL DRY WEIGHT—POUNDS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	28.1	25.5	46.0	48.5	71.5	88.9	87.5	96.7	128.4	168.4
A	35.1	65.9	78.1	86.2	92.1	97.4	110.4	125.7	174.0	173.9
B	.....	.....	.....	.....	.....	.....	121.0	158.5	219.5	171.4
C	.....	62.2	65.7	67.4	77.6	79.4	97.0	129.7	152.6	204.5
D	.....	.....	.....	.....	.....	.....	90.7	132.0	145.3	182.0
S.D.	9.20	15.13	15.54	22.44	22.73	20.91	42.36	32.62	61.36	63.36
C.V.	26.2	23.6	21.6	29.2	26.8	23.7	40.5	23.9	35.5	34.6
M.d.r.	.....	ns	11.4	16.4	ns	15.3	ns	ns	ns	ns

TABLE 22

K_2O IN TOTAL DRY WEIGHT—POUNDS PER ACRE

Plots	3½ mos. Sept.	5½ mos. Nov.	7½ mos. Jan.	8½ mos. Feb.	9½ mos. Mar.	10½ mos. Apr.	11½ mos. May	14½ mos. Aug.	17½ mos. Nov.	20½ mos. Feb.
X	143.1	139.6	234.0	224.4	311.7	333.4	331.2	274.1	444.6	680.9
A	216.8	425.8	457.6	427.4	463.1	479.3	575.8	467.0	600.4	782.6
B	.....	.....	.....	.....	.....	.....	616.3	582.6	779.6	856.2
C	.....	448.6	438.0	369.2	437.4	455.8	560.1	485.9	597.3	951.3
D	.....	.....	.....	.....	.....	.....	503.8	448.7	513.4	895.4
S.D.	80.8	101.78	113.51	105.90	100.40	126.12	229.93	98.26	191.85	288.26
C.V.	37.3	23.3	25.3	26.6	22.3	27.0	40.8	19.8	30.8	33.1
M.d.r.	.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
JUNE 16, 1944, TO SEPTEMBER 15, 1944

Date	Per pound	Per ton
June 16, 1944, to September 15, 1944	3.75¢	$75.00